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INVESTIGATIONS OF THE UPPER ATMOSPHERE AND OUTER SPACE CONDUCTED IN 1970 IN THE USSR

Report to the Fourteenth Meeting of COSPAR,
Seattle, Washington, USA

M. I. Shtern, Ed.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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In 1970, the Soviet Union continued its successful investigations of outer space.

Cosmonauts completed a long flight in the manned spacecraft Soyuz-9. Great success was achieved in studying the moon. Luna-16 obtained a sample of lunar soil and delivered it to the earth. Luna-17 put the self-propelled vehicle Lunokhod 1 on the moon and the latter traveled the first kilometers ever on the lunar surface. The interplanetary station Venera-7 landed on the surface of Venus. Satellites are in use for communications, television, and for obtaining weather information.

As in the past, the earth's atmosphere was studied, and medical and biological investigations were made, as were others.

Cooperation with socialist and other countries in the "Interkosmos" program is expanding.

This report contains short descriptions of the principal results of space investigations, materials from which were processed, wholly, or in part, in 1970.

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I. Investigations of the Moon and Planets

1. In accordance with the program for investigating the moon, 1970 saw the accomplishment of the launching of automatic space stations for making soft landings on the moon, expanding significantly the possibility of using automatic equipment in space investigations. /5*

The automatic space station Luna-16 (Figure 1) landed on the dark side of the moon on September 20, 1970, proceeded to bore and scoop out lunar soil, and then, aided by a rocket, accomplished a launch from the lunar surface, thus ensuring the delivery of the returning capsule (Figure 2) with the lunar material to the earth (Figure 3).

On November 17, 1970, the automatic space station Luna-17 delivered Lunokhod-1 (Figure 4), a self-propelled automatic vehicle, to the lunar surface. This was the first mobile automatic laboratory in astronautics. It was controlled from the earth and was designed for the complex study of the features of the lunar surface, the lunar environment, and distant objects in deep space. The space vehicle was thus the first to study the landing site, as well as the surrounding region. Topographic, geologic, and morphologic features of the locality were studied at the same time that chemical composition and the physical and mechanical properties of the lunar soil along the path traversed by Lunokhod 1 were determined.

Moreover, data on radiation along the flightpath to the moon, in near-lunar space, and on the lunar surface were gathered. An X-ray telescope measured the intensity and angular distribution of X-ray radiation and cosmic rays, as well as of individual sources.

The experiments in laser location of the moon using the French corner reflector installed on Lunokhod 1 were successful. The useful life of Lunokhod 1 showed it to be a highly dependable vehicle and the use of similar systems is quite promising.

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*Numbers in the margin indicate pagination in the foreign text.

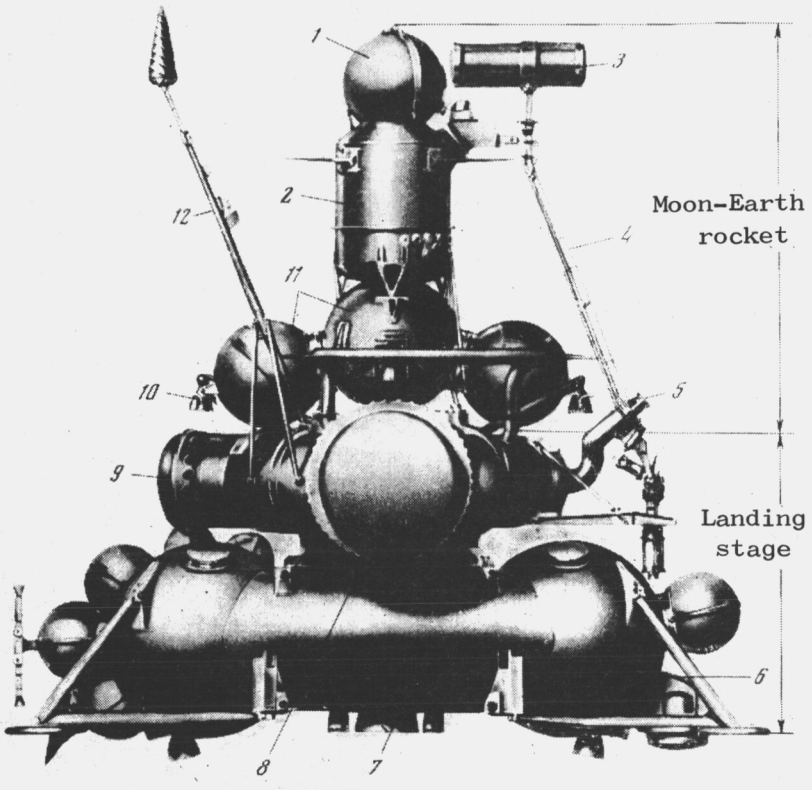

Figure 1. The automatic space station Luna-16.

1 - returning capsule; 2 - rocket instrument compartment; 3 - boring mechanism; 4 - boring mechanism rod; 5 - telephotometer; 6 - fuel tank; 7 - landing stage engine; 8 - moon-earth rocket engine; 9 - landing stage instrument compartment; 10 - control nozzles; 11 - rocket fuel tanks; 12 - antenna.

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The landing site of Luna-16 ($0^{\circ}41'$S, $56^{\circ}18'$E) at the northeastern tip of the Sea of Fertility is approximately 800 km to the east of the closest of the Apollo spacecraft landing sites (Apollo-11). The characteristics of this mare correspond to those of the other of the moon's equatorial maria, all of which show traces of a comparatively gentle subsidence and have the dissected contours of a shoreline.

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The landing site for Luna-17 ($38^{\circ}17'$N, $35^{\circ}00'$W), and explored by Lunokhod-1, is in the northwestern part of the Sea of Rains, almost 2500 km from the Luna-16 landing site. This is the northernmost part of the moon explored by landing vehicles.

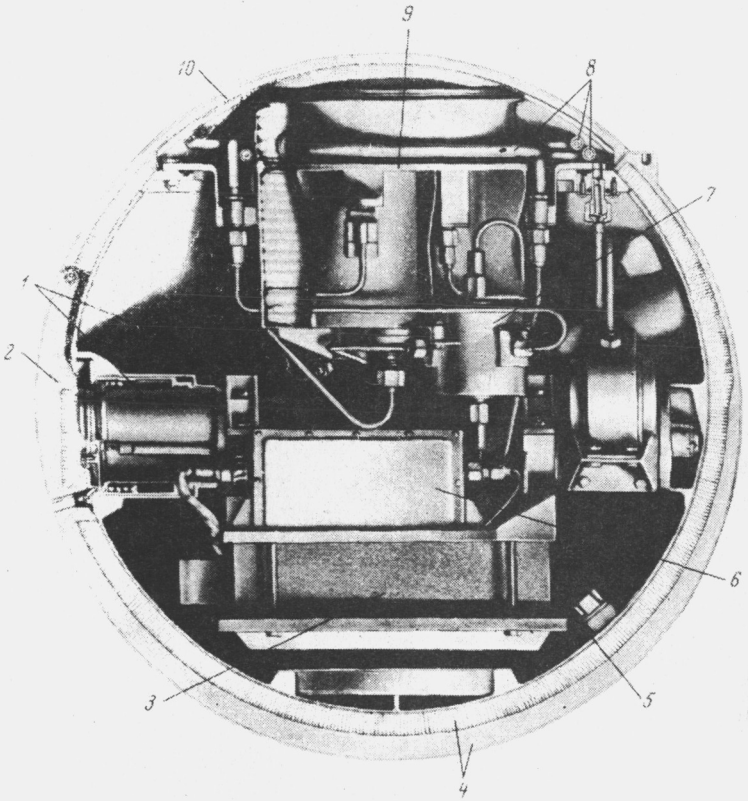

Figure 2. Returning capsule of the automatic space station Luna-16

1 - container for lunar soil; 2 - container cover; 3 - storage battery; 4 - heat protection; 5 - returning capsule housing; 6 - transmitters; 7 - antenna switch; 8 - antenna; 9 - parachute compartment; 10 - parachute compartment cover.

The landing site can be characterized as one most typical of a circular mare rimmed by shoreline mountain ridges usually associated with catastrophic type processes.

2. The lunar soil sample delivered to the receiving laboratory (Figure 5) was subjected to dosimetry, biological, and toxicological monitoring but, as previous investigations made in the United States have shown, this was unnecessary. The sample was thoroughly investigated. /8

The core of loose lunar soil (regolith) was 35 cm long, and was transported on a receiving tray. While it seemed to be homogeneous throughout its length (Figure 6), it did show an increase in the median size of grains from 70 to 120 microns. The regolith was found to have a mean density in its

natural occurrence of 1.17 g/cm^3, but this varied from 1.1 to 2.3 g/cm^3, depending on bulk and compacting conditions. The specific heat of the regolith was determined as 0.17 $kcal\text{-}kg^{-1}\text{-}degree^{-1}$. The normal albedo increased somewhat in the red rays (0.086 in the ultraviolet, 0.107 in the visible, and 0.126 in the infrared regions of the spectrum). The mirror component is clearly noticeable on the reflection characteristic curve.

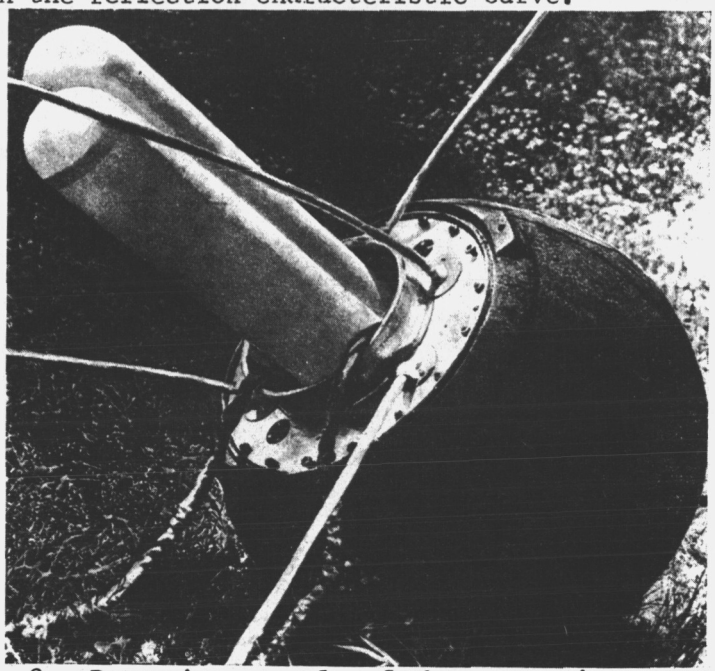

Figure 3. Returning capsule of the automatic space station Luna-16 after landing on earth.

The physical and mechanical properties of the regolith change significantly with degree of compaction.

The lunar soil holds a vertical wall well (Figure 7), and the particles adhere readily to each other, forming individual lumps.

The soil, in its loose state, is highly compressible, has a low shear strength, and low bearing capacity. There is a sharp improvement in mechanical properties when soil compaction is increased.

The regolith grains are quite varied in terms of mineralogical and petrographical characteristics and can be broken down into two main types: grains of primary magmatic rocks of the basaltoid [sic] type; and particles that had been subjected to noticeable modifications on the lunar surface. To be noted among them are traces of powerful, instantaneous fusion, resulting in the whole gamut of sintered, fused, and spherical particles, which are droplets of the silicate melt that solidified in flight.

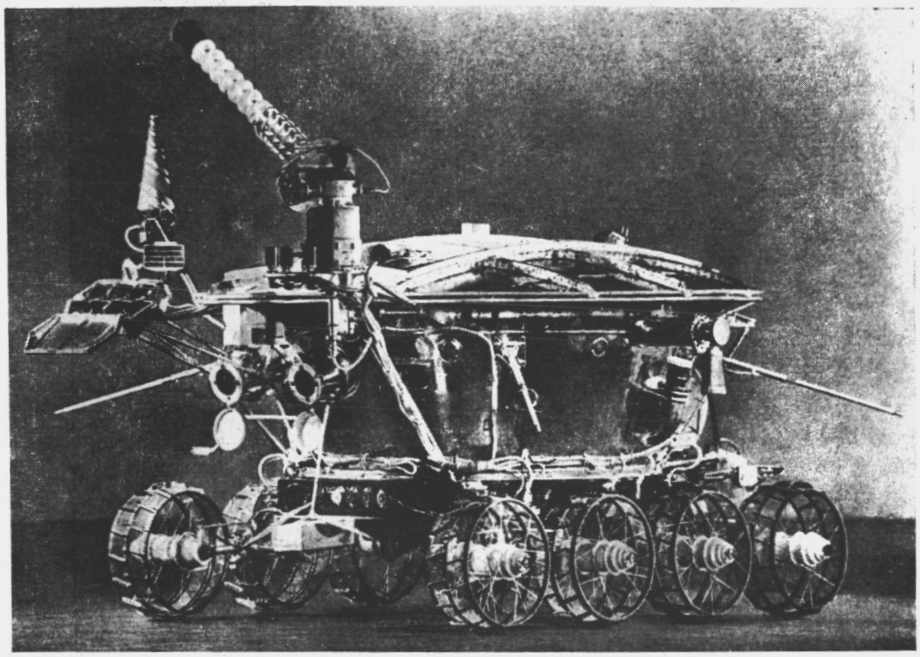

Figure 4. The self-propelled automatic vehicle Lunokhod-1.

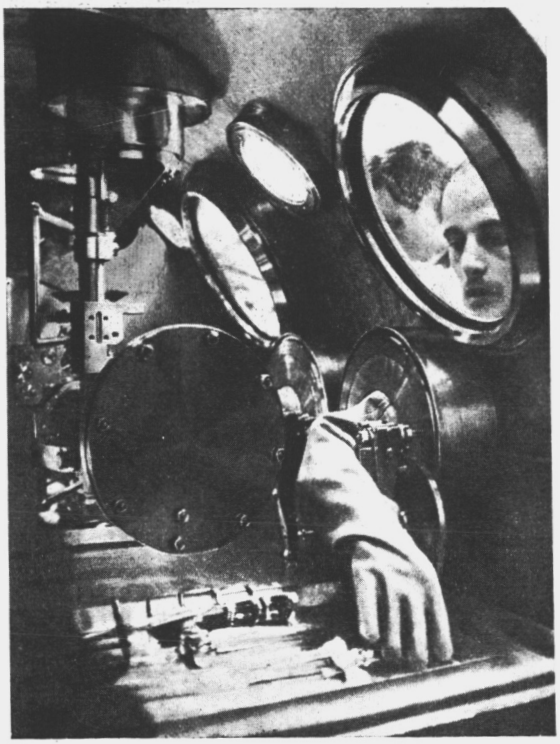

Figure 5. The receiving chamber for investigating the lunar soil.

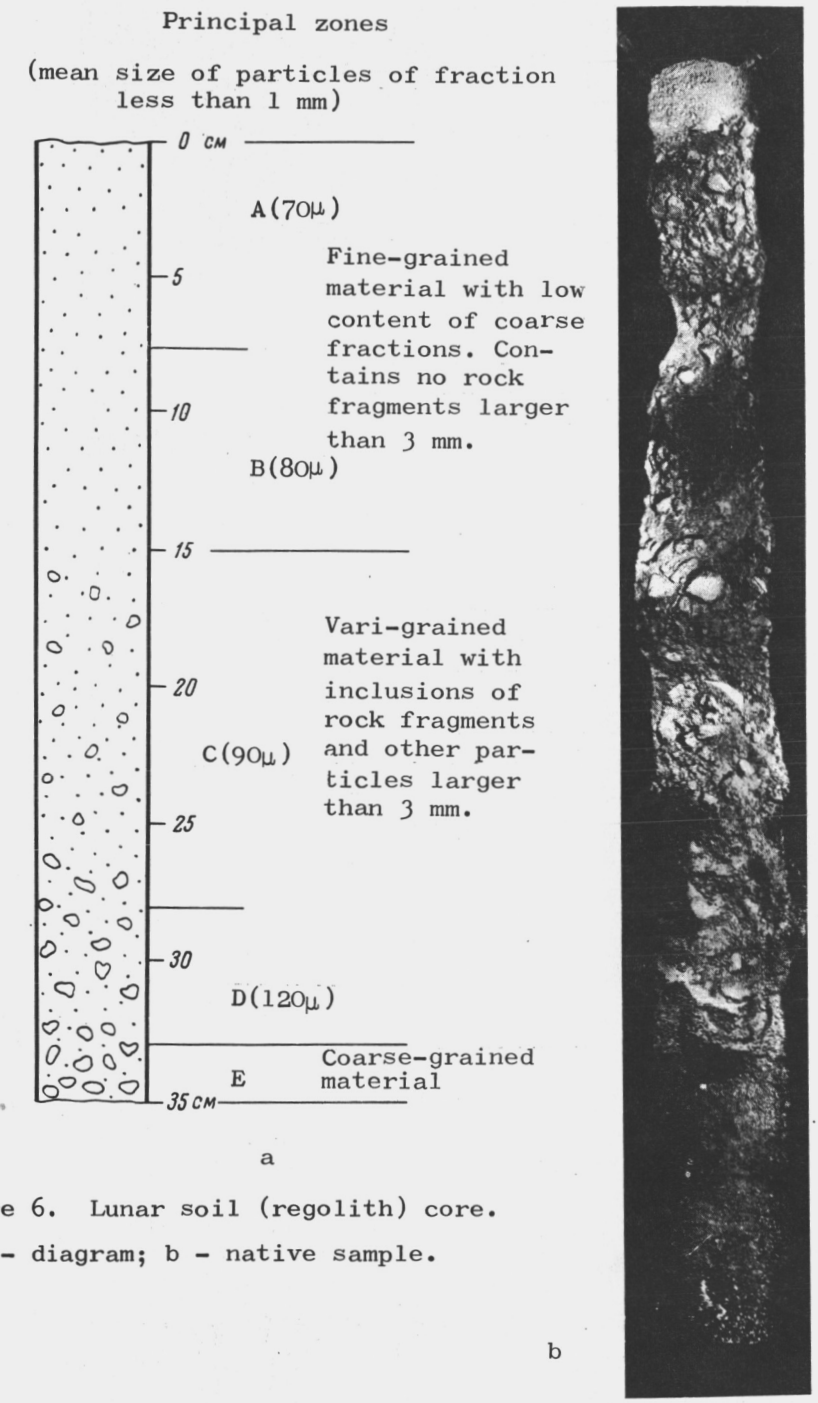

Figure 6. Lunar soil (regolith) core.
a - diagram; b - native sample.

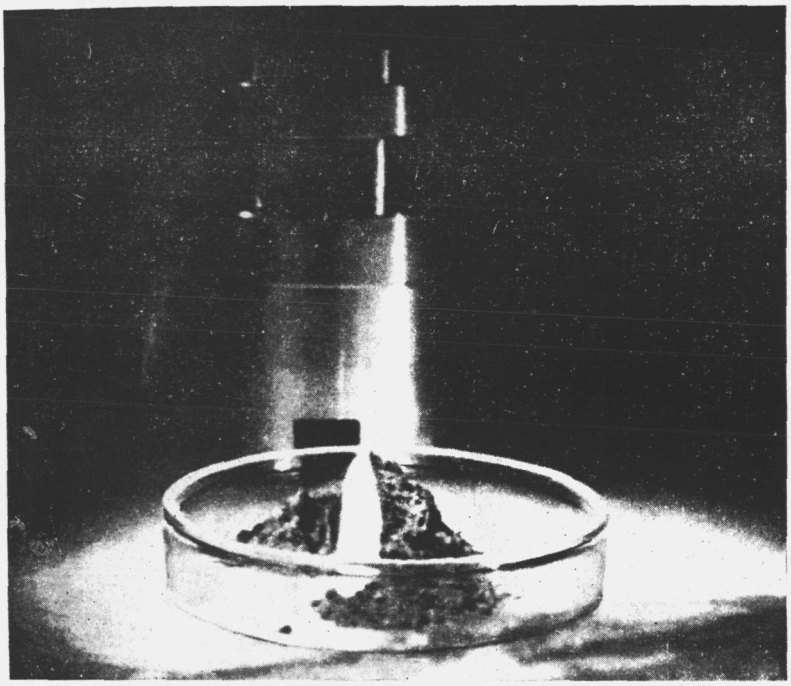

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Figure 7. Mound of lunar soil holding a vertical wall well.

Table 1 shows the nature of the particle distribution in the coarse fractions of the regolith.

It is of interest to note the appreciable amount of anorthite (anorthosite) in the lunar regolith (Figure 8).

TABLE 1. DISTRIBUTION OF NUMBER OF PARTICLES OF ASSORTED ROCKS IN TERMS OF FRACTIONS OF GRAINS LARGER THAN 0.45 MM AND PRINCIPAL ZONES, A, B, C, D OF THE SECTION (IN %).

Rock	A	B	C	D
Gabbro	13.1	17.5	8.1	15.2
Basalt	7.3	9.0	4.9	7.9
Anorthosite	1.1	3.7	2.5	4.5
Breccia	33.9	41.4	35.5	8.3
Scoriae and sinters	40.0	17.5	41.8	53.6
Glasses and single mineral grains	2.3	4.0	6.2	6.1
Globules	1.2	1.3	1.2	1.6
Miscellaneous	1.2	5.7	- -	2.6

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Detailed chemical analyses of the regolith, and of its fractions were made, and the majority of the elements were determined from the Mendeleev table. Table 2 lists the lunar soil composition.

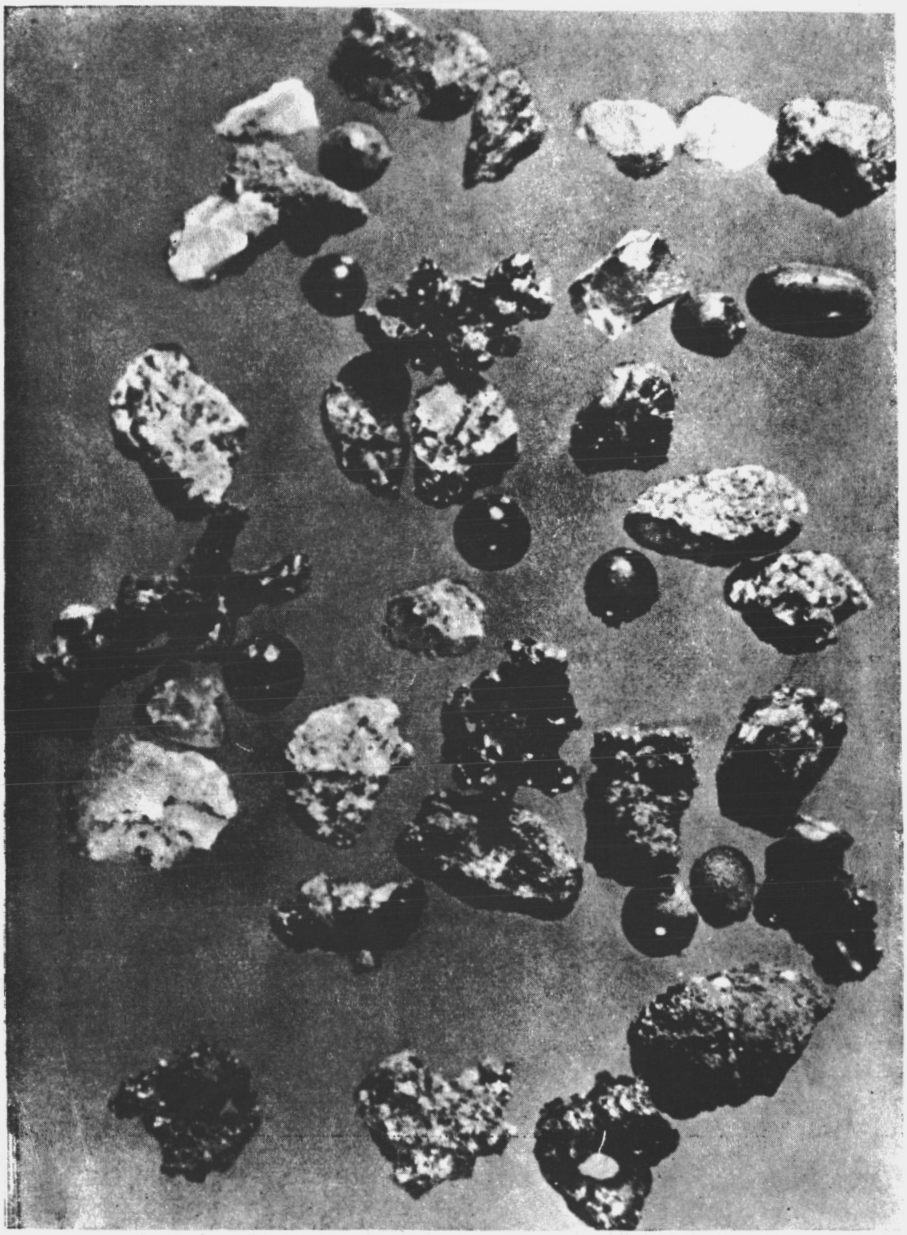

Figure 8. Types of lunar soil particles (fractions of grains larger than 0.45 mm).

TABLE 2. COMPOSITION OF THE LUNAR SOIL BROUGHT BACK FROM THE SEA OF PLENTY BY LUNA-16

	Grains of Basalt	Fine Fractions		Grains of Basalt	Fine Fractions
SiO_2	43.8	41.7	N_2O	0.33	0.37
TiO_2	4.9	3.39	K_2O	0.15	0.10
Al_2O_3	13.65	15.32	MnO	0.2	0.21
FeO	19.35	16.8	Cr_2O_3	0.28	0.31
MgO	7.05	8.73	ZrO_2	0.04	0.015
CaO	10.4	12.2			

What must be pointed out in comparing the composition of the fine-grained part of the regolith with the composition of crystalline lunar rocks is that the regolith is relatively enriched with plagioclase and depleted of pyroxene, olivine, ilmenite, and spinel. In other words, crystalline rocks have a more mafic composition than does the regolith (Figure 9).

Solar wind gases, which have a high concentration, are the domimant components of the regolith gas composition, and it is here that lunar rocks differ so significantly from earth rocks and meteorites.

Determination of the absolute age of the fine fractions of the regolith using the Rb/Sr method yielded an isochrone mean of 4.45 and 4.46±0.5 billion years. Values close to these also were obtained with Pb^{206}/Pb^{207}.

It can be considered as established, therefore, that the lunar maria for the most part are areal outcroppings of rocks of basaltic composition, as had been supposed on the basis of the study made of the gamma-spectra of the lunar surface obtained by Luna 10 in 1966. /15

A comparison made with data obtained by American reasearchers reveals that the regolith is a regional surface formation, the characteristics of which are quite constant and change within limits on the surfaces of the lunar maria, that corresponds to the optical homogeneity of the lunar maria known from astronomical observations. With respect to the diversity of the mineral composition of the regolith, the thought is that it is formed right on the site of its occurrence, and, at the same time, that the components of its particles

can be transported over considerable distances, thus resulting in an averaging out of regolith characteristics.

Study of the lunar soil sample is continuing.

Figure 9. A particle of coarse-grained lunar basalt under the microscope. Polarized light, Nicol prism +.

3. Processing of the data obtained by Luna-17, and brought back to its station on the lunar surface by Lunokhod-1, is continuing.

Altimeter readings along the Luna-17 flightpath provided an overall height profile of the surface of the Sea of Rains, showing it to be a plain dissected by a system of ridges 300 to 500 meters high, and complicated by individual crater-like shapes.

Movement of Lunokhod 1 made possible a very detailed study of the morphology and distribution of craters and rocks along its path over a distance of several kilometers. In turn, this made possible a statistical study of small shapes within a large area, something that had not been permitted to other types of space vehicles. The most interesting of the geological and morphological formations, in terms of characteristics of chemical composition and physical and mechanical properties of the soil in various sections of the lunar surface, on the plain, as well as in regions of crater ejections and inside a number of craters, were studied on a selective basis. Study of numerous fresh craters made it possible to develop the nature of the ejections of rocks from craters less than 30 meters in diameter, and to determine variations in the regolith thickness.

A survey of the lunar landscape was the basis for a topographic study of the terrain. This included television panoramas (scores) and photographs (several hundred), as well as telemetry on length of path traveled, and measurements of course, and the list and trim of Lunokhod 1 while it was moving.

The results of the survey included the compilation of a topographic map of the track at a scale of 1:1000, rectified maps of individual sections at a scale of 1:200, topographic plans of individual sections at a scale of 1:100, and heights of track profile, and characteristics of craters, from a study of stereo pairs. /16

A topographic survey of the track over 3,600 meters long and up to 150 meters wide, was made during the first three lunar days. Results of the operational work done are shown on the topographic map (Figure 10).

The geologic and morphologic description of the region was arrived at by studying the panoramic pictures (a fragment of one is shown in Figure 11) and using the topographic characteristics of the terrain, data on variations in the physical and mechanical and chemical properties of the soil and the

positions of the vehicle along the track. Geologic and morphological maps of sections where Lunokhod-1 stopped were obtained and a number of conclusions with respect to characteristics of the region investigated were reached.

This region of the Sea of Rains resembles the maria regions of the moon's equatorial zone previously studied, in general morphology, nature of the regolith, and propagation of craters and rocks. This is indicative of the generality in the behavior pattern of the formation and evolution of the lunar surface over a considerable expanse of lunar maria.

Established was the fact that craters with smooth shapes predominate among the small craters (those with diameters less than 30 meters), and that there are very few fresh rocky craters with sharp relief. This shows that the process of crater formation has been a lengthy one, and that their shapes have changed with age because of destruction that has tended to soften their shape. Most such craters are of impact-explosion origin. The presence of most of the rocks on the lunar surface is the result of their ejection from craters. A comparison of shapes of rocks in the ejection zones shows that they become rounded and smooth with the passage of time.

A variety of rocks of different shapes and colors were observed, but the overall geologic structure of the region studied is typical of lunar maria. This structure consists of thick basaltic lava flows covered by from 1 to 5 meter thick layers of regolith.

RIFMA* spectrometric equipment was used to make a rapid analysis of the chemical composition of the lunar soil along the path taken by Lunokhod-1. This was done by studying the X-ray spectra obtained from gamma-irradiation of the soil by an isotope.

The chemical composition at many sites with characteristic geologic and morphologic features was measured, as was the composition of individual rocks, of undisturbed soil surfaces, and of rocks 5 to 10 cm deep. Variations in content of aluminum, calcium, silicon, iron, titanium, and other elements, were determined. ∠19

The data confirm the origin of the regolith as the result of breakdown of rocks, in the main those of basaltic composition.

*Translator's Note: Expansion is unknown.

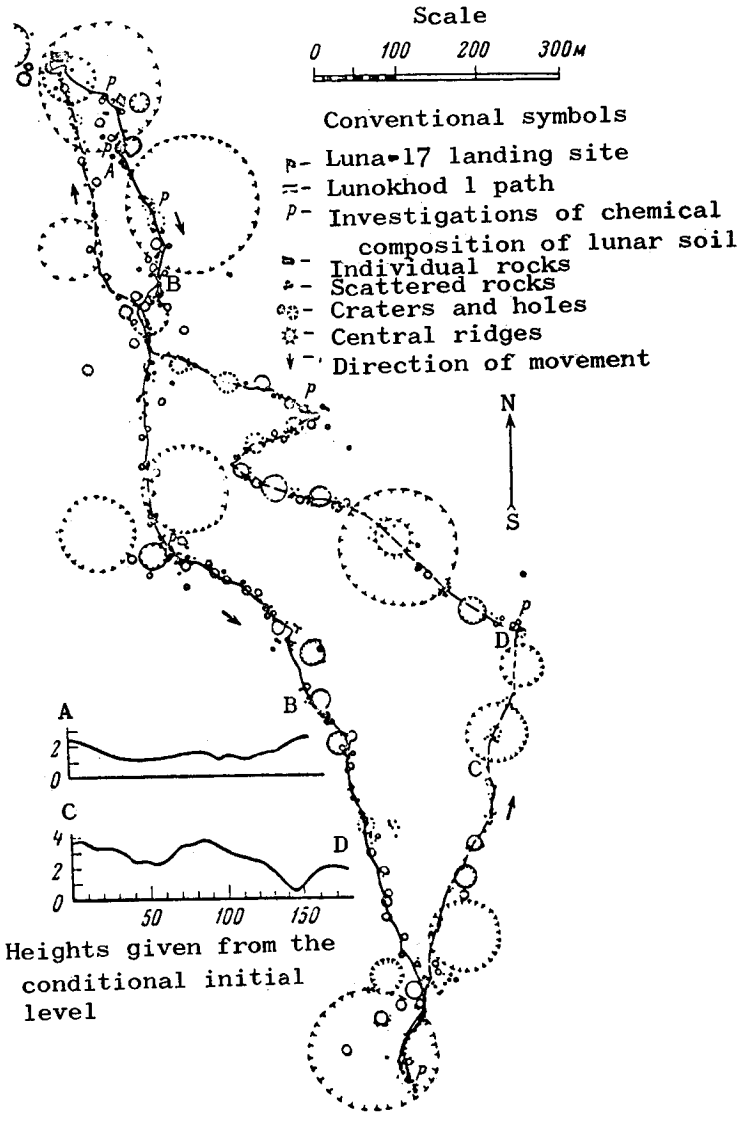

Figure 10. Topographic map of path of Lunokhod-1 during the first three lunar days.

The physical and mechanical properties of the lunar soil were determined in several ways. One was by the insertion of a conically-shaped shovel-like boring tool into the soil (Figure 12) and the turning it. Another was by measuring the interaction between the wheels of Lunokhod-1 and the soil. Yet another involved analyzing the pictures of the tracks left by the vehicle.

The regolith along the path over which the vehicle moved is a fine-grained material, for the most part, with little cohesiveness. Its bearing capacity ranges from 0.2 to 1.1 kg-cm^{-1}, and its resistance to rotational shear from

0.02 to 0.09 kg-cm^{-1}. Good compaction of the upper layer, together with an increase in bearing capacity, was noted when the boring tool was buried repeatedly.

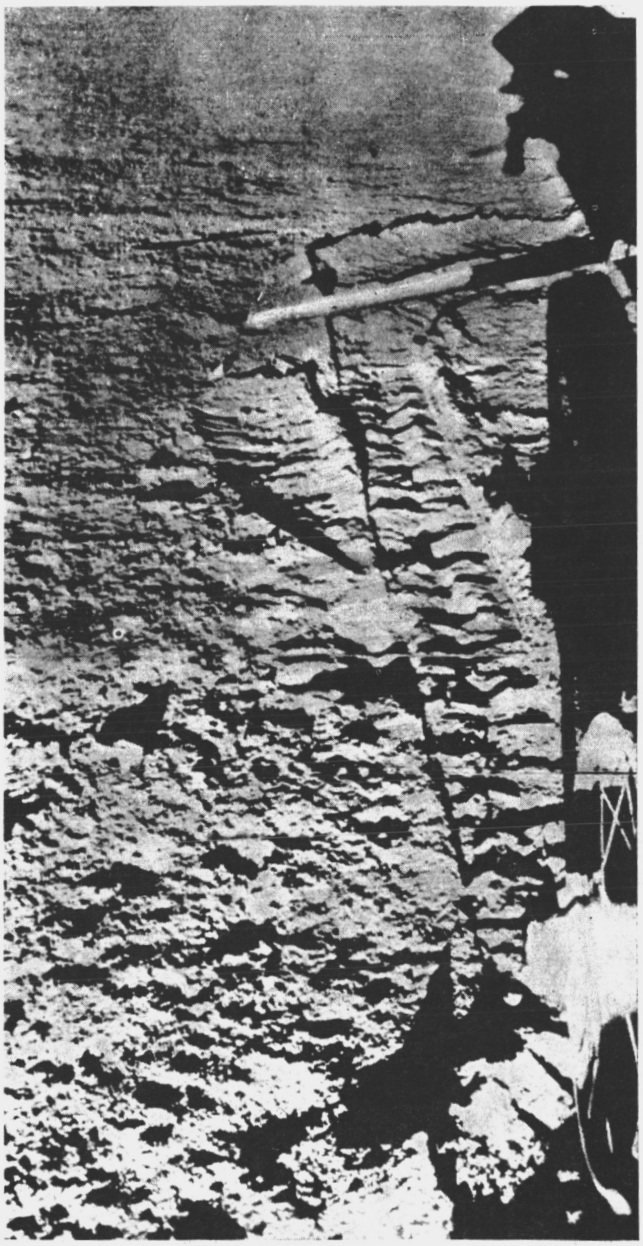

Figure 11. Fragment of one of the panoramas of the lunar surface.

Processing the results of the experiments conducted with Lunokhod-1 is continuing.

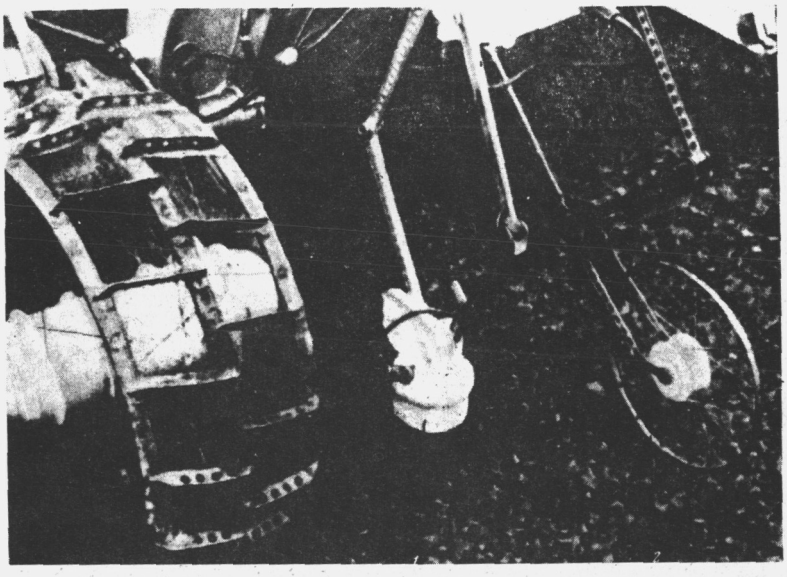

Figure 12. Lunokhod-1 instruments for investigating the physical and mechanical properties of the lunar soil.

1 - penetrometer; 2 - "fifth" wheel.

4. New data on the figure and relief of the moon were obtained from photographs of the moon's western hemisphere, taken by Zond-6. /20

Profiles of cross-sections in planes close to the direction to the earth were studied from pictures of the lunar limbs. Analysis of these profiles resulted in finding previously unknown formations on the far side of the moon in the region of its south pole, including a broad depression, 4.7 km deep, and prominences up to 10 km high.

The combined statistical processing of coordinates of points in lunar catalogs, and of measurements in pictures of the points on the photography provided some estimates of random errors in the catalogs. /21

5. The automatic interplanetary station Venera-7 (Figure 13) was launched toward Venus on August 17, 1970, from an artificial earth satellite in orbit. The descent vehicle landed on Venus on December 15. The landing was made on the far side, approximately 2000 km from the morning terminator.

The descent vehicle (Figure 14) of Venera-7, as distinguished from the vehicles used with preceding stations, was designed to probe and investigate the Venusian atmosphere, and to provide for the operation of scientific equipment on the planet's surface. The design incorporated a new housing and newly /22

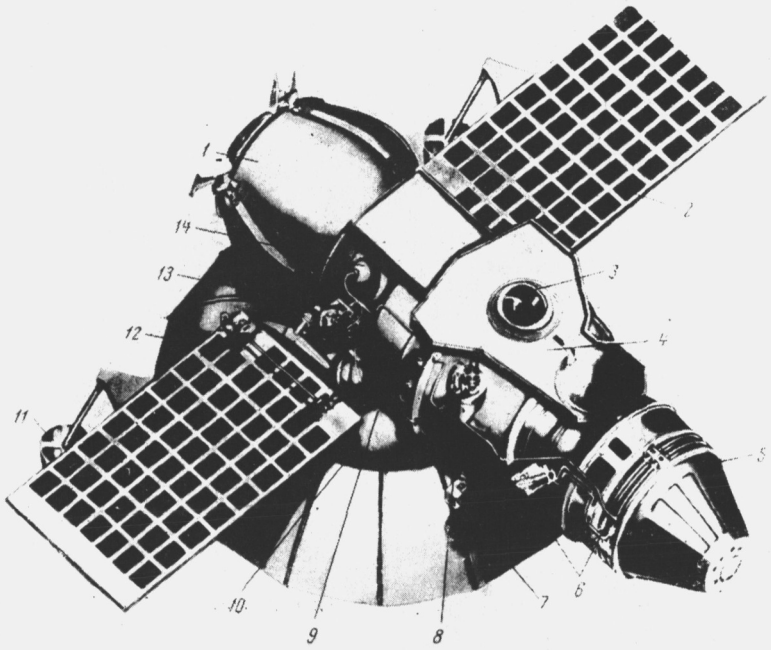

Figure 13. The automatic interplanetary station Venera-7.

1 - descent vehicle; 2 - solar-cell banks; 3 - sensor for astronomical orientation; 4 - protective panel; 5 - correction engine; 6 - pneumatic system manifolds with control nozzles; 7 - cosmic ray counter; 8 - sensor for constant solar orientation; 9 - orbital compartment; 10 - radiator-cooler; 11 - moderate directivity antenna; 12 - beam antenna; 13 - pneumatic system automatic unit; 14 - compressed nitrogen bottle.

developed heat insulation with a special composition to provide the descent vehicle with protection against the extremely high temperatures and pressures encountered upon entering the planet's atmosphere, while descending on the parachute, and after landing on the surface. The descent vehicle carried equipment for measuring temperatures between 25 and 540°C, and pressures between 0.5 and 150 atm. The vehicle also carried highly stable frequency generators. They were tuned, and compared with the frequencies generated by standard generators on the ground several times during the flight. This made it possible to measure the rate at which the vehicle was descending in the Venusian atmosphere with a high degree of accuracy.

Change in the frequency of the radio signal at the end of the descent phase established the fact that the rate at which the vehicle had been descending

relative to the planet had become zero. In other words, the vehicle had landed. Change in the frequency of the on-board transmitter recorded after this point in time corresponded exactly with the rate at which that part of the Venusian surface upon which calculations showed the vehicle to have descended was moving relative to the earth.

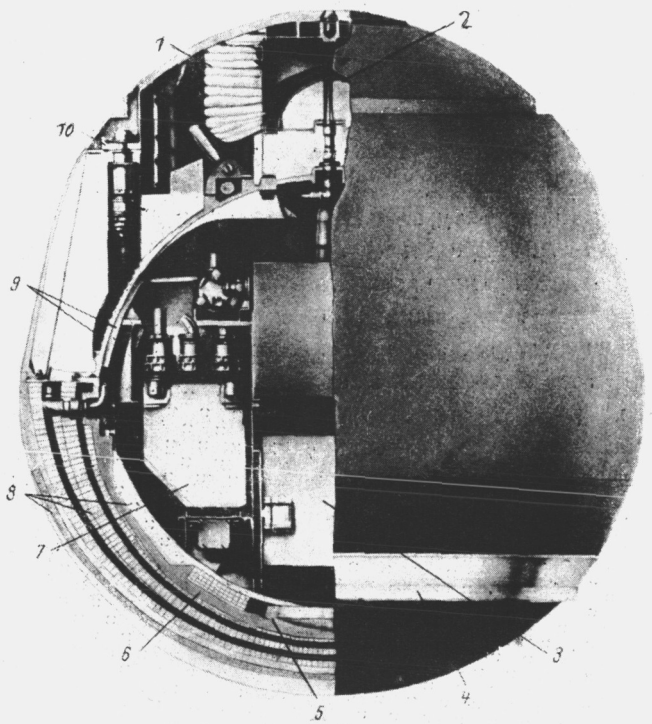

Figure 14. The descent vehicle of the automatic interplanetary station Venera-7.

1 - parachute; 2 - transmitting antenna; 3 - radio transmitter; 4 - support ring; 5 - damper; 6 - strength housing; 7 - switching unit; 8 - heat insulation; 9 - heat exchanger; 10 - parachute compartment cover.

The signals from the descent vehicle were received for 23 minutes. Signal strength was weaker than it was during the descent by a factor of approximately 100. The most probable explanation is the tilt in the axis of the antenna from the direction to earth after landing on the surface. A special procedure, involving the use of electronic computers, was used to separate this weak signal and decode the information transmitted.

Throughout the descent, and after landing, the descent vehicle of Venera-7 transmitted information on the temperature of the environment only, because

this is the most important characteristic of the structure of the planet's atmosphere. The vehicle encountered a steady rise in temperature with descent. The temperature of the environment remained practically unchanged for the entire time the radio transmitter was in operation on the Venusian surface.

Temperature changes in the atmosphere from altitude down to the planet's surface were determined from the results of measurements made of the temperature of the atmosphere and the rate of descent versus time. It was found that the law of change in temperature was close to adiabatic right down to the surface.

Measurements previously made by Venera-4, Venera-5, and Venera-6 in the Venusian atmosphere helped establish the connection between temperature and pressure up to heights of 20 km. The height distribution of pressure and density of the atmosphere of Venus from altitude to the surface was calculated by using equations of hydrostatic equilibrium and gas state and incorporating these data with the results of the Venera-7 measurements. /23

Allowing for possible errors in measurements, it was possible to estimate allowances that had to be made for temperature and pressure values obtained. Atmospheric parameter values on the surface at the site where the descent vehicle landed are $475 \pm 20^{\circ}C$, and 90 ± 15 atm.

Direct measurements of temperature, pressure, and chemical composition of the atmosphere of Venus, made by Venera-4 through Venera-7, provided the basis for significant advances in concepts concerning physical features of the Venusian atmosphere. A model of the planet's atmosphere, containing the most important characteristics of its troposphere and stratosphere, was constructed. Direct measurements were used to calculate the attenuation and refraction of radio waves in the atmosphere of Venus. The results of recent radar observations of the planet in the centimeter and decimeter bands were processed with these data taken into consideration. Consideration of the attenuation and refraction of radio waves using a spherical-symmetrical model of the atmosphere of Venus provided the means for determining the pattern of the back-scattering from the planet's surface, and to calculate the mean-square angles of inclination of the surface, σ_{α}, on bases of the order of 10 wavelengths in the band of frequencies $\lambda = 3.8$ to 70 cm.

The calculations showed that reduction in the base results in an increase in σ_{α} in this band from 5° to 8° (if the influence of the atmosphere is

disregarded the results of the ground radar measurements correspond to independence of σ_α from the base).

A comparison of the results of calculations of σ_α values for identical wavelengths in the centimeter and decimeter bands for the moon and Venus shows that σ_α is larger by a factor of 2 for the moon than it is for Venus, while retaining the nature of the increase in σ_α with shortening of the base.

6. Ground investigation of the moon, and of the planets, has continued.

Moon. A complete structural and geologic map of the moon has been drawn. Observations have been made in the submillimeter band in order to determine brightness temperatures.

Mercury. Phase changes in radiation from Mercury in the submillimeter band have been measured.

Venus. A small diurnal change in the temperature of the atmosphere ($\leq$ 1%) at heights of from 20 to 50 km, has been established from radioastronomical investigations of the phase dependence of Venus at λ = 8.2 mm.

Mars. The distribution of energy has been studied for continents, maria, and polar caps in the spectrum between 3900 and 8600 Å. Calculations have been made of transparency and brightness of the sky on Mars.

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Jupiter. Polarimetric and photometric observations have provided the value of the optical thickness of the gas layer (less than 0.2) and mean radius of the particles of the cloud layer (of the order of 0.3 microns). A hypothesis with respect to the vortical nature of the big red spot has been formulated. The densities of the flows of radio radiation at 8.2 mm have been measured.

Saturn. Absolute spectrometry of Saturn from photometric observations in the visible part of the spectrum, and relative spectrometry of the disk and rings in the ultraviolet has been undertaken. An increase in the reflectivity of the planet's disk at wavelengths shorter than 3800 Å has been detected. Brightness temperature of radio radiation from Saturn at 8.2 mm (132 $\pm$ 4°K) has been measured. It was found that the optical thickness of Saturn's rings is less than 0.3 at this wavelength.

Uranus. The brightness temperature of radio radiation at 8.2 mm (134 $\pm$ 10°K) has been measured. Ammonia is the most probable component of Uranus' clouds.

II. Investigations of Cosmic Rays, and the Interplanetary Medium, and the Magnetosphere

1. In 1970, the processing of the information obtained by space station Proton-4, launched on November 16, 1968, and designed to study particles of high and superhigh energy primary cosmic rays, continued. /25

The artificial earth satellites Proton-1, Proton-2, and Proton-3 previously had used direct methods to measure the energy spectrum of all particles (protons and heavier nuclei) of primary cosmic rays in the energy range $5 \cdot 10^{10}$ to 10^{14} ev. The Proton-4 experiment was a step forward in studying the spectrum of all particles in the range of considerably higher energies all the way to $4 \cdot 10^{15}$ ev. Figure 15 shows Proton-4 results of measuring the primary cosmic ray spectrum.

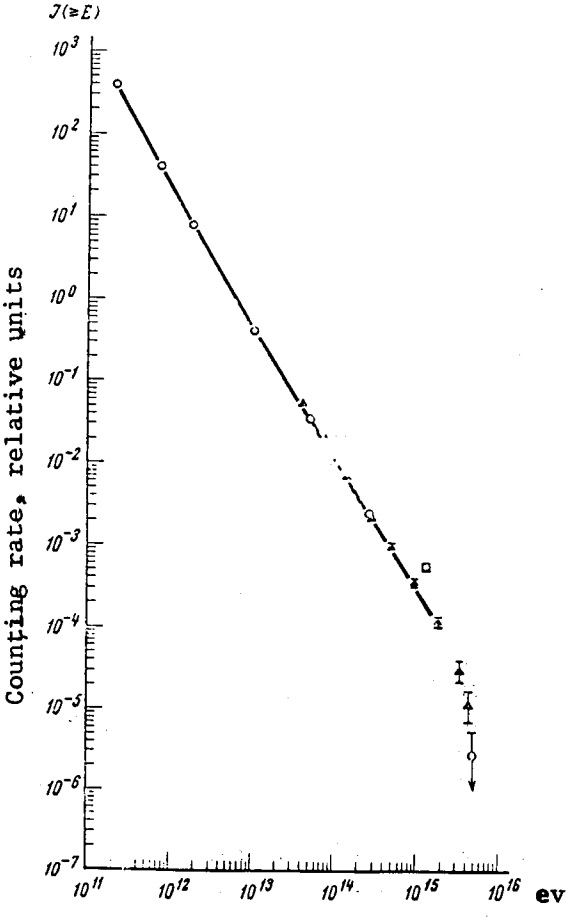

Figure 15. Energy spectrum of all particles (protons and heavier nuclei) of primary cosmic rays measured by Proton-4.
o - integral amplitude analyzers; ▲ - differential amplitude analyzer.

The direct methods used by Proton-4 established the fact that at energies higher than $2 \cdot 10^{15}$ ev the energy spectrum of primary cosmic rays will be steeper.

Measurements made by Proton-1 through Proton-4 have revealed that the integral energy spectrum of primary cosmic rays in the energy range between 10^{13} and 10^{15} ev is a purely power-law spectrum with exponent $\gamma = 1.6$. Particles of primary cosmic rays with energies in this range are responsible for the formation in the atmosphere of particles with energies between 10^{12} and 10^{13} ev. At the same time, the energy spectra of nucleons and γ-quanta, measured at various depths in the atmosphere, are steeper and have exponents $\gamma = 1.9$ to 2.0. This means that existing concepts relative to the constancy of the principal characteristics of nuclear reactions (of effective cross sections of inelastic reactions, of coefficients of inelasticity) in this energy range should be reviewed.

The result of analysis of data from the Proton stations was the detection of irregularity in the spectrum at energies $\sim 10^{12}$ ev, evidently indicating a change in the chemical composition of the primary cosmic rays in this energy range. The existence of irregularity in the spectrum of all particles is shown in Figure 16 (in order to better show the deviation of the measured spectrum from a purely power law, the spectrum is shown in the coordinates $\log[J(\geq E)\, E^{\gamma}]$ and E, where E is particle energy, J is particle intensity). The dots in Figure 16 show the measurement of the spectrum of all particles by Proton-1, Proton-2, and Proton-3, the crosses the data obtained by Proton-4. It should be pointed out that irregularity is observed in the energy range where, according to the Proton-1, Proton-2, and Proton-3 measurements, the energy spectrum of the protons of the primary cosmic rays becomes steeper.

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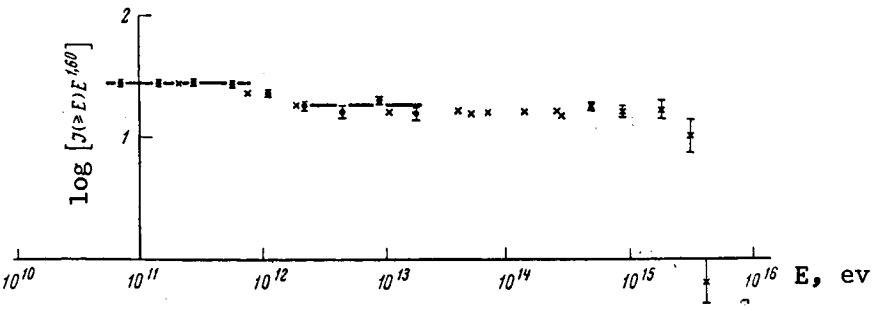

Figure 16. The magnitude $\log[J(\geq E)E^{\gamma}]$ in terms of energy (when $\gamma = 1.60$) for the average of all series of measured values obtained by Proton-1, Proton-2, Proton-3, and for one series of measurements by Proton-4.

Proton-3 was first to use direct methods of measuring the energy spectrum of α-particles of primary cosmic rays to energy of 10^{12} ev/nucleon (Figure 17). The streams of α-particles recorded in the 10^{10} to $5 \cdot 10^{10}$ ev/nucleon range are in good concordance with the data in the literature.

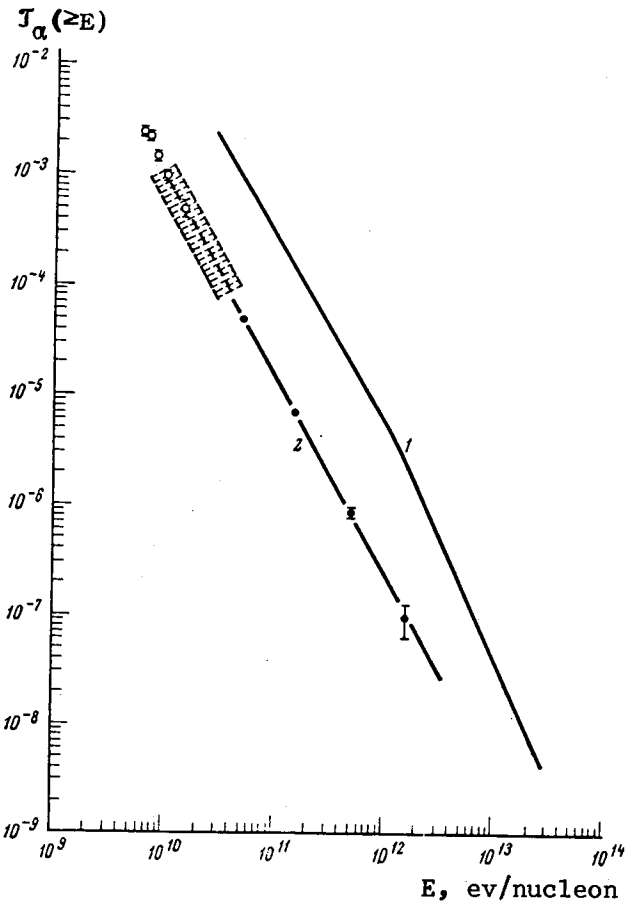

Figure 17. Spectrum of protons measured by Proton-1, Proton-2, and Proton-3 (1) and energy spectrum of α-particles of primary cosmic rays (2).

● - Proton 3 data; o - data by K. C. Anand et al; hatched portion data by K. Pinkan et al.

2. Proton-2 and Kosmos-208 investigated the intensities of the γ-quanta of high energies in primary cosmic radiation. These experiments yielded upper limits of intensity of the isotropic background of primary γ-rays with energies from 30 to 1500 Mev (Figure 18). The magnitudes of these limits, based on the data from Kosmos-208 measurements, are lower than those obtained in the experiments by Kraushaar and Clark, and by Kirillov-Ugryumov et al. This was the first time that measurements were made over a wide range of energies.

The information obtained concerning the arrangements of the γ-ray spectrum at energies greater than $3 \cdot 10^7$ ev argues against the hypothesis that the contribution from the decay of the π^0-mesons forming in deep space as a result of the reaction between cosmic rays and gas is the predominant one. Best concordance with the experiment is noted for the calculations of reactions between relativistic electrons and relict radiation.

3. In 1970, measurements of isotope and element composition of corpuscular streams in deep space were continued by the manned spacecraft Soyuz-9, and by the automatic interplanetary station Zond-8. The method used was that of collection in specially prepared targets.

Soyuz-9 studied the streams of H^3 (30 to 80 Mev), He^3 (70 to 180 Mev), and He^4 (80 to 200 Mev) nuclei between June 1 and 17, 1970. Total exposure time was $1.5 \cdot 10^6$ seconds. The target used to study the energy spectrum of the nuclei in these ranges was a set of plates made of specially purified aluminum. Laboratory analysis of the target by a highly sensitive mass spectrometer with high resolution and weak-background counters revealed that over the above-indicated time span the streams of nuclei were not in excess of 0.4 cm^{-2}-sec^{-1}-$ster^{-1}$ for H^3, 0.06 cm^{-2}-sec^{-1}-$ster^{-1}$ for He^3, and 100 cm^{-2}-sec^{-1}-$ster^{-1}$ for He^4. /28

The Zond-8 experiment studied the element and isotope composition of the corpuscular streams from the sun. The target had an area of 300 cm^2 and was a set of foils of different thicknesses for gathering nuclei with energies ranging from 0.5 kev/nucleon to 3 Mev/nucleon. The target was exposed for $5 \cdot 10^5$ seconds when oriented with respect to the sun. Measurements showed that target temperature did not rise above 140°C at any time during the experiment. This caused no noticeable loss of solar wind ions gathered by the target. Target analysis was made using the same set of laboratory equipment used to measure the Soyuz 9 target. The Zond-8 target also was used to measure stable and radioactive isotopes of inert gases, as well as H^3. The long time the target was exposed to the sun resulted in the number of isotopes gathered by the target being considerably in excess of the background content of these isotopes in the material. /29

The results of the analysis of the isotope composition of the solar wind obtained during the flight of Zond-8 were compared with the results of determining

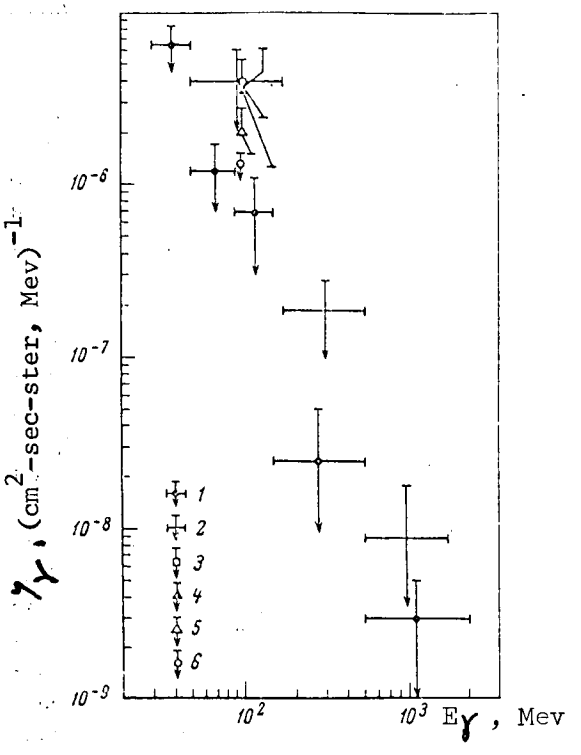

Figure 18. Differential energy spectrum of γ-quanta of primary cosmic rays.

1 - Kosmos-208; 2 - Proton-2; 3 - Explorer-XI; 4 - Kosmos-264; 5 - OSO 3 (M. F. Kaplon); 6 - OSO-3 (W. L. Kraushaar).

the concentration and isotope composition of the inert gases in lunar soil samples returned by Luna-16. The fine fraction of the lunar soil (particle sizes ≤ 40 microns) taken at depths between 0 and 8, and 15 and 28 centimeters below the lunar surface was measured. The comparison revealed that the content of inert gases in the fine fraction of lunar soil is determined for the most part by accumulations of such gases from solar wind streams. Moreover, no significant changes were found in concentrations and isotope composition of inert gases in samples taken from different depths below the lunar surface.

4. A great deal of information on the intensity of low-energy solar and galactic cosmic rays in interplanetary space was obtained from the equipment installed in Venera-7 between August and December 1970.

Two large, complex shapes of increase in the intensity of solar cosmic rays, and many small ones, were recorded during the four months.

The first of these began on November 5, and lasted for over ten days. The nature of the change in the intensity, in the energy spectrum, and in the

anisotropy is indicated by the systematic observation initially of diffusive, and then of convective, motion of solar cosmic rays from the powerful flares that occurred on November 5, 1970.

The second, the largest increase, began on December 12, 1970. The December 13 proton intensity maximum, when energies of from 1 to 5 Mev were recorded, exceeded the background level by a factor of approximately $5 \cdot 10^5$. This increase in solar cosmic rays, and the Forbush decrease in galactic cosmic rays associated with it, was caused by the series of powerful flares that occurred on December 10 and 11, 1970.

The decrease in the first big increase, and the entire second increase, were recorded by the equipment installed on Lunokhod-1 during the flight of Luna-17 to the moon, and then on the lunar surface. Thus, between November 10 and December 15, 1970, streams of cosmic rays were recorded simultaneously at two points in interplanetary space quite a distance apart (as much as $6 \cdot 10^7$ km). /30

The values for the mean intensities of galactic and solar cosmic rays obtained during the flight of Venera-7, made it possible to close the 11-year variation in the intensity of galactic cosmic rays, the first reading of which was obtained in 1959 (Luna-1) and to continue the study of the variation in the intensity of solar cosmic rays that was begun in 1965 (Zond-3).

5. Kosmos-378 was orbited on November 17, 1970. Its principal purpose is to make a continuous, complex study of the ionosphere (and of its polar regions in particular). The satellite has equipment for measuring all of the most important characteristics of the ionosphere, such as concentrations of electrons and ions, and their temperatures, using a variety of probing methods. The satellite is also carrying two identical electrostatic analyzers with angular patterns oriented in opposite directions with resolution of $\Delta E/E = 0.3$, and an angular resolution $\sim \pm 15^\circ$ for studying streams of electrons with energies between 0.8 and 10 kev. Semiconductor and gas-discharge counters also are carried to study streams of electrons with energies $E > 40$ kev, and of protons with energy $E \geqslant 1$ Mev. A magnetometer is carried to establish orientation of meters with respect to the magnetic field. Data obtained by the satellite will be processed and compared with data from a great many ground geophysical observatories making observations at the time the satellite is flying over the /31

areas in which they are located. According to preliminary data, captured and quasi-captured electrons with energies $E > 40$ kev have been observed at night to $L \simeq 8$, and in the daytime to $L \sim 10$ to 12. The gap between the inner and outer radiation belts is found at $L = 3$. Streams of protons with $E > 1$ Mev, with intensity 5 to 10 cm^{-2}-$ster^{-1}$ at L from 15 to 38, have been observed at the polar caps during perturbed periods. Numerous spectra and pitch distributions of the streams of electrons with energies between 0.8 and 10 kev have been recorded. The pitch distributions are sharply anisotropic, and often have two maxima near pitch angles $\theta = 0$, and $\theta = \pi/2$. Electron streams flowing toward the earth usually are noticeably more intensive than those flowing in the opposite direction. Rapid variations in the spectrum and intensity, often by two orders of magnitude with characteristic times $\lesssim 1$ second, are observed systematically. In most cases, the energy spectrum maximum occurs at $E < 1$ kev (according to preliminary data processing).

Figure 19 is an example of the data from measurements made by Kosmos-378 on November 18, 1970, during a magnetic storm of sudden commencement at 12^h25^m UT. Figure 19 shows the readings taken by one of the electrostatic analyzers measuring flows of electrons with energies of from 0.8 to 10 kev (averaged every 3 seconds), by the semiconductor and gas-discharge counters measuring the flows of electrons with energies $E > 40$ kev, and of protons with energy $E_p \gtrsim 1$ Mev (averaged every 13 seconds), and by the spherical probe for measuring the electrons of the ionospheric plasma, T_e, by the high-frequency method (averaged every 15 seconds). These data cover the period between 15^h22^m and 15^h40^m ($K_p' = 4+$) and were obtained approximately 3 hours after the commencement of the magnetic storm.

As will be seen, intensive streams of electrons with $E > 0.8$ kev were recorded during the magnetic storm in the region $L \sim 3.5$ to 6.9 on the night side of the earth between local times 21^h and 4.5^h in the morning. Energy was in excess of $\sim$ 10 to 20 erg-cm^{-2}-sec^{-1} at individual times. There are distinct boundaries to the region in which streams of electrons with energies < 10 kev /33
were recorded and there is a dip in their intensity near local midnight. This correlates well with the nature of the change in streams of harder radiation, as well as with the behavior of electron temperature, T_e, in the ionosphere. All of these features were recorded in the readings of the second electrostatic analyzer, and comparison of readings from both analyzers will make it possible

to evaluate the stream of electrons "reflected" by the ionosphere, something that varies greatly with pitch angle and time of observation. Note the 1000 to 2000°K change in temperature recorded in the region of electron outpouring.

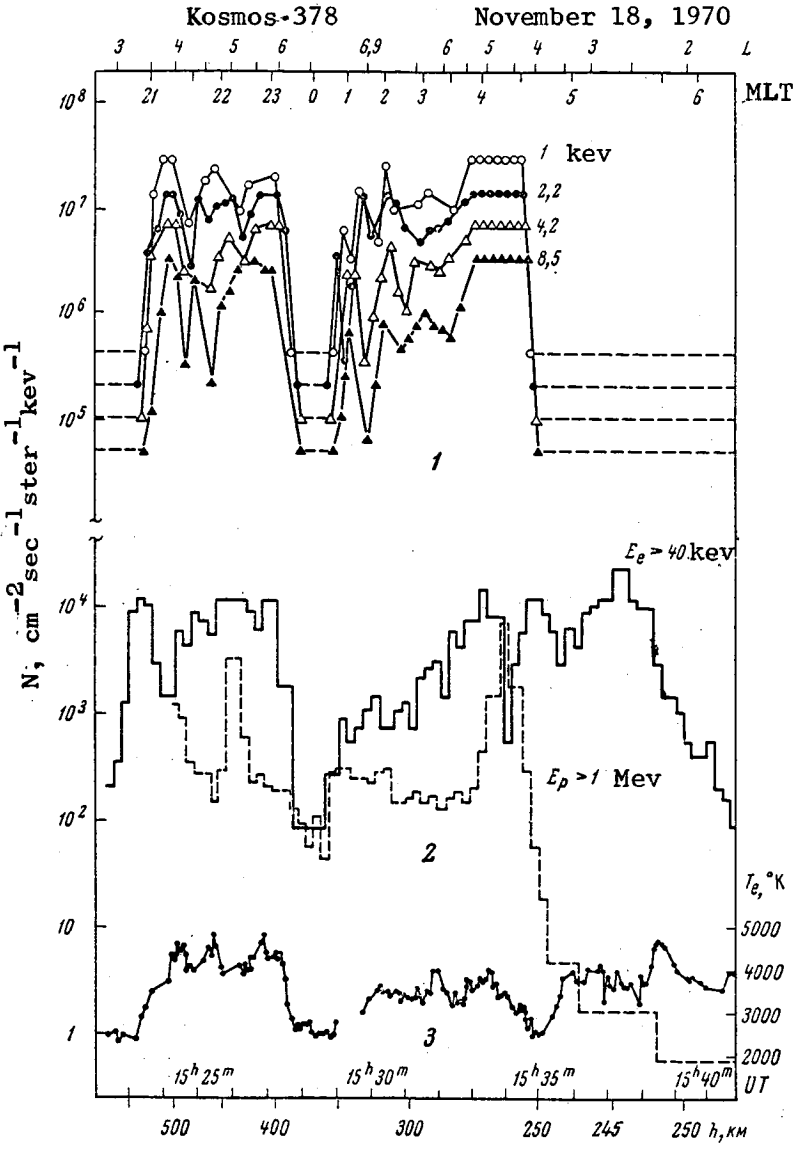

Figure 19. Measurements made by the satellite Kosmos-378 on November 18, 1970.

1 - stream of electrons with energy 0.8 to 10 kev; 2 - stream of electrons with energy E > 40 kev and of protons with energy $E_p \gtrsim 1$ Mev; 3 - stream of electrons of ionospheric plasma, T_e.

To be noted as well is the correlation between T_e and the streams of electrons with energies E > 40 kev.

6. An experiment designed to record ONCh* signals and noise was conducted for the first time in the Soviet Union in 1970, using the artificial earth satellite Interkosmos-3. The satellite carried an ANCh-1 instrument (frequency range 0.5 to 15 kHz, sensitivity 10^{-14} w/m^2Hz), and a UHF-FM transmitter for relaying signals recorded by the satellite to receiving points. This experiment was accompanied by a broad program of ground observations of like signals. Scientists from Czechoslovakia, Bulgaria, and East Germany participated in the experiment within the framework of the "Interkosmos" program.

The Interkosmos 3 observations lasted for four months (from August 7 to December 6). Some of the important features already can be pointed out:

(a) because of the ellipticity of the orbit, the height of the satellite above the reception points twice changed from 200 to 100 km; that is, the satellite delivered information on the nature of signals at different heights at different periods of its existence;

(b) the signals received have certain distinguishing features never before described (quasi-periodically modulated whistling atmospherics, for example, as well as others);

(c) a great many signals occurring as a result of the reaction between the primary electromagnetic wave and the surrounding plasma were recorded.

7. Kosmos-321 was assigned an experiment under the World Magnetic Survey program. The satellite carried a quantum cesium magnetometer to measure the scalar magnitude of the geomagnetic field. Information was obtained for 94 percent of the earth's surface, making possible the compilation of a map of the secular variation in the geomagnetic field for the period 1964-1970. These same data will be used to obtain a new mathematical model of the geomagnetic field for the 1970 period.

Information on the March 9, 1970, storm was obtained for three successive /34
revolutions of the satellite. These data are being used to study the geometry, and the dynamics, of the oval from all of the on-board and ground data.

8. Kosmos-381 was launched on December 2, 1970. The ionosphere probe carried by the satellite is to probe the ionosphere at 20 frequencies in the band from 1 to 16.9 MHz. Equipment for observations of low-frequency radiations will permit studying oscillations between 0.5 and 15 kHz. A number of

*Translator's Note: ONCh = very low frequency (VLF).

meters will record the sun's electromagnetic radiation between 1 and 1500 Å, and streams of high-energy particles (protons with energies in the tens of Mev, and electrons with energies greater than 100 kev).

The satellite also is carrying a high-frequency impedance probe operating at a frequency f = 3 MHz, the purpose of which is to measure electron concentration, and its heterogeneity. The probe's sensor is a 90-cm-long metal whip. This probe will measure the electron concentration in the ionosphere, N, from 10^3 to $6 \cdot 10^4$ e/cm^3, and its heterogeneity, ΔN, from 10 to 1400 e/cm^3 with dimensions from 0.7 to 150 km. Preliminary results of processing measurements from several transits of the satellite have revealed that the heterogeneity of the electron concentration has a broad spectrum, from 1 to 150 km. The intensity of the relative fluctuations in the electron concentration, $\Delta N/N$, in the ionosphere at 1,000 kilometers varies greatly, from $5 \cdot 10^{-4}$ to 10^{-1}. Still, the mean electron concentration for the ionosphere is between $4 \cdot 10^3$ to $4 \cdot 10^4$ e/cm^3 for all transits. Fluctuations in the electron concentration are most intense in the polar latitudes (74° to 60°N), weakest between 60° and 50°N, and once again intensify between 50° and 40°N. Heterogeneities with dimensions of 200 km and more, with relative fluctuations in electron concentration equal to several tens of percent are found.

9. A number of new conclusions were reached in 1970, from the data obtained from a complex experiment designed to investigate the auroral effects in the upper atmosphere by coordinating the measurements made by Kosmos-261 and ground geophysical observatories in the Soviet Union, Bulgaria, Hungary, East Germany, Poland, Rumania, and Czechoslovakia, during the period 1968-1969, as part of the Interkosmos program.

A. The energy spectra, and the distribution in terms of pitch angle, of super-thermal electrons in the energy region between 30 and 150 ev in the upper atmosphere, of photoelectrons in the ionosphere illuminated by solar ultraviolet radiation, and of auroral electrons in the near-polar and polar latitudes, were measured. The spectrum of ionospheric photoelectrons is close to that calculated theoretically. The pitch distribution is almost isotropic, and is indicative of free transition of photoelectrons with the energies indicated from one hemisphere to the other along the magnetic field force tubes. /35

The auroral electrons with energies ~ 100 ev above the polar caps have a pitch distribution with a predominant longitudinal component. Their

intensities above the summer (illuminated by the sun) polar cap are approximately twice those above the winter cap. Energy spectra are not constant. Two maxima, one in the several tens of electron-volt range, and one in the several hundreds of electron-volt range, often can be observed. The data obtained for low-energy auroral electrons are in concordance with available data from optical ground measurements of the glow of the auroras at the polar caps. Deep minima in the intensity of low-energy electrons have been found within a radius of about 1,000 km in the near-polar region of the south and north polar caps.

B. Measurements of auroral electrons in the 1 to 150 kev range (eight energy ranges) revealed that the pitch distribution of the electrons in the background (the so-called "mantle") glow of the auroras after midnight can be characterized:

(a) by isotropy in the lower hemisphere, and by "reflection" of electrons from the atmosphere only as a result of coulomb scattering, for the range from 1 to 50 kev;

(b) by a constant transition to a quasi-captured pitch distribution by virtue of increase in energy to $\sim$ 100 kev, with pitch distributions for energies $\geq$ 100 kev having a clearly expressed cone of losses. These data can be used to evaluate the pitch angle diffusion coefficient in terms of energy. This is of importance in analyzing the mechanism of this diffusion in the magnetosphere during polar substorm phenomena.

The disappearance of electrons with energies $\sim$ 15 kev at the polar caps (inside the ovals of the auroras), and the simultaneous increase in the intensity of electrons with energies $\sim$ 1 kev and less, corresponding to the recently detected "soft zone" of the auroras, have been confirmed.

C. Measurements of auroral protons and ions in the 40 ev to 9 Mev energy range (eleven energy ranges) revealed that the pitch distribution of the auroral particles usually has a maximum near $\theta = 90^{\circ}$ (and near 70° for lower energies). These are quasi-captured particles, therefore, although there are, in addition to this larger-scale component, small-scale intrusions with almost isotropic, or even longitudinal pitch angle distributions. The unavailability of information on effective cross-sections of the excitation of emission from /36
Balmar lines upon intrusion of protons into the atmosphere precludes the making of an unequivocal interpretation of the data from ground measurements of the

emission from hydrogen in the auroras in view of the measurements of the distributions of intrusive auroral protons (ions) obtained.

The conception of the development of a magnetic substorm was proposed, the basis being the picture of primary auroral particle distributions obtained, together with new data in the literature concerning the processes taking place in the outer magnetosphere and in the solar wind during substorms in 1970.

Briefly, this conception is as follows:

(a) a higher energy component (protons ~ 10 kev) appears in the solar wind (mean proton energy ~ 1 kev);

(b) these particles can penetrate the magnetosphere in the so-called "plasma layer," on the evening and before-midnight side of the magnetosphere;

(c) these protons and ions with E ~ 5 to 20 kev have "resonance" properties in the earth magnetosphere, because the rate of their gradient drift in the magnetic field of the L-shells of the auroras is equal in magnitude, approximately, and opposite in sign to the rate of their electric drift attributable to the diurnal rotation of the magnetosphere plasma with the earth such that these particles, when in a nonrotating system of coordinates (fixed with respect to the direction of the solar wind), always will be on the night side of the magnetosphere and their motion will be determined solely by the asymmetry of the magnetic field and by the electric fields in the magnetosphere;

(d) as a result of the particles losing energy (in particular, by the Joule dissipation from the electric fields of polarization occurring in the lower lying ionosphere), the resonant particles are capable of accumulating in the potential wells that occur on the night side of the magnetosphere, creating clouds of quasi-captured hot protons and ions with energies of about 10 kev;

(e) the appearance of azimuthal asymmetry of the quasi-captured protons (this corresponds to asymmetry of the ring current)causes the appearance of an electric field on these L-shells that takes in the entire magnetosphere at local time, and this, in turn, changes the character of the drift of all the cold and energy-captured particles in these regions of the magnetosphere;

(f) it can be assumed that the accumulation of particles continues until the achievement of some threshold, after which there is some as yet unidentified instability, such as a "magnetospheric explosion" or "magnetospheric

substorm". As a result of the appearance of large, fluctuating, induced electric fields, there is, at this time, a considerable acceleration of the particles in the magnetosphere, and a sharp increase in the stream of particles in the cone of losses, corresponding to the flare of the auroras;

(g) the process of generation of a substorm can be repeated in the event of continuing "pumping" of the magnetosphere by resonant particles from the solar wind. /37

The different aspects of the conception suggested here are now being compared with experimental data in order to verify it.

10. The second complex experiment (Kosmos-348) under the Interkosmos program was conducted in the summer of 1970. The sensitivity of many of the instruments carried by the satellite was increased, and some additional improvements were made (ion temperature in the ionosphere was measured, in particular), but in the main the content of the experiment was the same as before in order to be able to compare these data with those from the winter experiment (Kosmos-261).

Detailed measurement of the energy spectrum of photoelectrons can be mentioned as being among the first results obtained (sensitivity was increased by more than an order of magnitude compared with the first experiment). Concordance with the theoretical calculations was better, but additional effects were found. Measurements of the shift in the photoelectron spectrum measured, in terms of energy of particles passing along the force tube from the adjacent ionosphere, and comparison with the spectra of particles originating in the ionosphere near the satellite, established that the difference in potentials between adjacent regions of the ionosphere is not in excess of 10 volts, which corresponds to an intensity of the longitudinal electric field of 10^{-8} volts per centimeter.

11. The oriented satellite Kosmos-320 was used in January 1970, in an experiment designed to measure the temperature and density of the upper atmosphere. The temperature of the nitrogen molecules was measured. The value of the density near the perigee corresponds to the density determined as a result of the braking of the satellite. Results are in the processing and analysis stage.

12. Observations of the coherent "Mayak" radio sets carried by Kosmos-321 and Interkosmos 2 by a widespread network of ground stations (eleven in the USSR,

and seven in the socialist countries) were made in 1970. The first processing of the recordings obtained is complete, and catalogues of orbital data have been calculated. Preliminary results of the scientific analysis of these observations were contained in the report to the international seminar held at the IZMIRAN [Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation of the Academy of Sciences of the USSR] between November 9 and 14, 1970, as part of the Interkosmos program. The seminar also was given a detailed report, including a discussion of the procedure used to investigate the ionosphere by using coherent radio waves emitted by artificial earth satellites. /38

13. A series of high-altitude, drifting balloons carrying equipment for investigating X-ray bremsstrahlung in the subauroral region (project Omega 1) were launched between January 25 and March 10, 1970, in Arkhangel'sk Oblast', continuing the series of Franco-Soviet experiments to study the phenomena in the magnetically adjacent regions, Kerguelen-Arkhangel'sk Oblast'. The chief purpose of the 1970 balloon launches was to prepare for the concluding stage of the complex experiment involving the simultaneous launching in the magnetically adjacent regions of balloons carrying identical equipment in combination with a broad program of ground investigations (ionosphere, geomagnetism, very low-frequency radiation, auroras, absorption of cosmic radio radiation, and the like) as part of the preparations for project Omega 2, planned for January-February 1971. The feasibility of making a short-term forecast of periods of magnetosphere perturbations was verified, wind conditions in adjacent regions were studied, and other investigations were made during the 1970 campaign.

The last of this particular series of balloon launches was completed successfully during the period when the widely known storm of March 8, 1970, was in its development period (apparently the most intensive storm during the current cycle of solar activity). Detailed analysis of solar and geophysical data conventionally furnished the Moscow Regional Warning Center (IZMIRAN), as well as analysis of operational information on the geophysical situation on the Kola Peninsula, and in Arkhangel'sk Oblast', provided by the Polar Geophysical Institute (Apatity, Murmansk Oblast') and by the Arkhangel'sk Magnetic and Ionospheric Observatory, made it possible to forecast the onset of the most perturbed period (although the intensity of the perturbation exceeded all expectations) and to make timely recommendations with respect to launching the balloons.

14. The high-altitude balloons measured electrons in the energy range from 100 to 1500 Mev at great heights in the atmosphere in positions with geomagnetic latitudes of 46°, 49°, and 58° N. Unusually heavy losses of electrons were recorded on days when magnetic substorms were observed at depths less than 50 g/cm^2 of residual atmosphere. The total general planetary index of magnetic activity for the day was $\Sigma K_p = 18$ to 23, and its change, as compared with the preceding quiet day, was $\Delta\Sigma K_p = 10$ to 13. Figure 20 shows the results of measurements at latitude 46°N, and it will be seen that at the time the two measurements were made (June 14, 1967, and October 27, 1967) the electron flux levels were in excess of those recorded at identical heights on other days by a factor of from 2 to 3. The additional electron flux occurring at the boundary of the atmosphere had a magnitude of ~ 0.1 $(cm^2\text{-sec-ster})^{-1}$ at the beginning of the substorm, but then diminished with time in accordance with a law close to exponential, diminishing by a factor of approximately 2 during the day. Figure 21 presents the experimental results obtained at different latitudes, indicating the change that takes place with time, as read from the beginning of the corresponding substorm, in the integral level (a), and in the index for the differential energy spectrum (b) for the additional electron flux. There is a hint of the connection between the additional electron flux and the auroral phenomena. It is possible that the recorded electrons occur, just as do the electrons causing the auroral phenomena, during acceleration in the magnetosphere, and are the high-energy part of the accelerated electrons penetrating to the middle latitudes. This assumption is in need of further experimental verification. /40

15. Three geophysical rockets of the Academy of Sciences of the USSR were launched to heights of approximately 500 km on April 27, May 16, and October 3, 1970. The scientific experiments conducted during these launches included measurements of electron concentration, n_e, using dispersed ultrashort waves from a radiointerferometer operating at frequencies of 48 and 144 MHz. A flat Langmuir probe, and the absorption of ultraviolet radiation from the sun, as determined by photoelectron analyzers, were the means used to make simultaneous measurements of electron concentration, n_e, and temperature, T_e. All measurements were made in the morning in the middle latitudes of the European part of the USSR.

The measurements resulting from the use of the dispersion methods provided $n_e(h)$ profiles. The USSR used a dispersion radiointerferometer in 1958, to

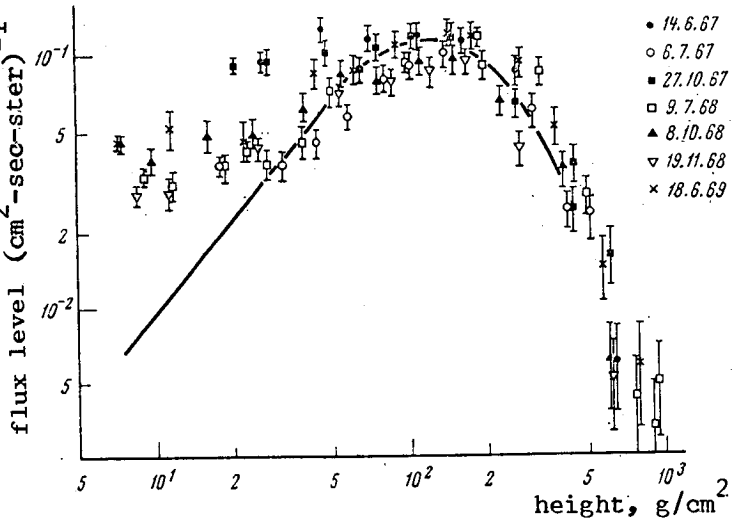

Figure 20. Results of measurement of height dependence of flux of electrons with energies of from 100 to 1500 Mev at the geomagnetic latitude of 46° N.

Solid curve: calculated course of secondary electron flux.

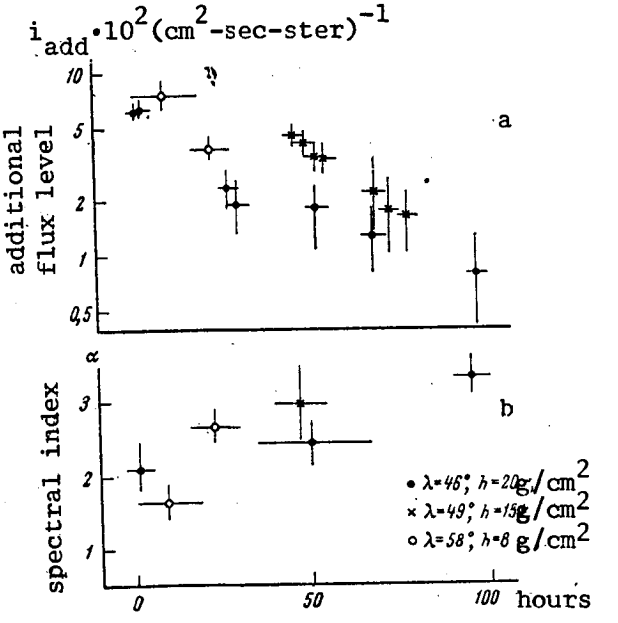

Figure 21. Change in terms of time, read from the beginning of the substorm, in the integral additional flux level (a) and in the index for the differential electrical [sic] spectrum, represented in power form (b).

make rocket measurements of n_e. It is convenient to use the $n_e(h)$ distributions obtained by the same method in the same region to make comparisons, and these distributions can be used to study changes that occur in the parameters of the ionosphere in terms of the phase of the cycle of solar activity.

The simultaneous measurement of the absorption of ultraviolet radiation and the concentrations, n_e, and temperatures, T_e, of solar electrons provides the means for estimating the parameters of the neutral and ionized components of the upper atmosphere and the constant for the main processes taking place in the upper atmosphere (ion formation rates, the recombination factor, and others).

Figure 22 is an example of an $n_e(h)$ profile constructed using data measured along the descending section of the trajectory of the rocket launched the morning of October 3, 1970 (sun about 8° above the horizon). The rocket reached a maximum height of 480 km. The circles show the results of the Langmuir probe measurements. /41

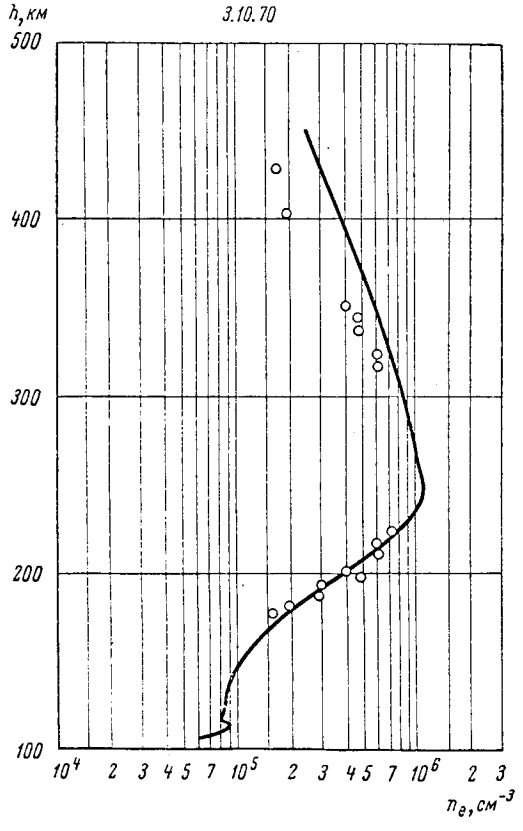

Figure 22. The $n_e(h)$ profile constructed from data measured on the descending section of the trajectory of the rocket launched on October 3, 1970.

The photoelectron analyzers installed in the rockets measured photoelectron emissions from the surface of the metal as a result of the ultraviolet radiation from the sun. Preliminary results of measurement processing reveal that the density of the total photocurrent at a height of 480 km was $\sim 4.5 \cdot 10^{-9}$ a/cm^2 on October 3, 1970.

16. The widespread use of ground equipment for investigating deep space around the earth, as well as theoretical investigations based on the data obtained from space vehicles, continued in 1970.

A. The materials from the Explorer 12 mission yielded individual quantitative dependencies of the geocentric distances to the subsolar point of the magnetosphere boundary on the intensity of the ring current DR (D_{st} index), on the intensity of the polar electron jets DP (indices AU, AL, Q) at the time the satellite intersects the boundary of the magnetosphere, as well as on the three-hour index K_p. Intensification of DR moves the boundary of the magnetosphere away from the earth, and intensification of DP moves it toward the earth. /42

It has been shown that ground observations of the position of the oval of auroras on the day side of the earth when using existing model representations of the geometry of the magnetic field in the magnetosphere provide for estimating the geocentric distance of the subpolar points. It was found that the dynamic pressure of the solar wind at the boundary of the magnetosphere was $P_\alpha = mnv^2$ when $K_p \leq 2$, and $P_\alpha = 0.8\ mnv^2$ when $K_p > 2$.

B. The data from the four satellites, IMP 1 through 4, and utilization of a modified double-dipole model of the magnetosphere, established the dependence of the invariant latitude Φ' of the near noon boundary of the magnetosphere on the orientation of the axis of the geomagnetic dipole relative to the plane of the ecliptic. The concordance between changes in Φ', obtained with the help of the model and observed in other geophysical phenomena, indicate the legitimacy of using this particular model to analyze the experimental data for various angles of inclination of the axis of the dipole relative to the plane of the ecliptic.

C. A planetary scheme has been derived for the development of an auroral substorm, in which, in addition to the dynamics of the auroras in the phase of development and recuperation, there is included the changes that occur in the auroras during the phase when the substorm originates. These changes are

closely associated with the processes in the plasma layer of the tail of the magnetosphere, as analysis of changes in the tail has revealed.

D. The results of the measurements made of ring current protons on September 8, 1966, by the satellite OGO-3 were compared with changes in the magnetic field at low- and high-latitude observatories. It has been shown that there is a depression in the magnetic field at low-latitude stations in the evening and day sectors between 3^h and 4^h UT, and that this depression is associated with the appearance of L = 4 to 6 ring current protons in the evening sector. Intense polar magnetic disturbances can develop in the high latitudes at this time. Absence of protons in the day sector between 6^h and 7^h UT reflects the time variations in particle intensity as a result of substorm abatement.

E. The development of the polar magnetic disturbance of December 24, 1966, was analyzed. It was found that the DP development is associated with the increase in particle flux in the night magnetosphere (ATS-1 data), and with the depression in the magnetic field at the satellite and at low-latitude observatories. What is very nearly a single-vortex current structure is observed /43 during intensification of the western currents (maximum for the depression in the low latitudes), and a two-vortex one is observed upon their attenuation. The eastern and western electron jets develop independent of each other and evidently are different in nature. The displacement to the west of the positive DP maximum in the aurora zone, as well as the magnetic field depression peak in the low latitudes, indicate that both of these effects are attributable to the longitudinal drift of protons with energies of $\sim$ 50 to 100 kev.

F. A space-time relationship method was proposed in order to separate the high-speed shock waves of the solar wind from the tangential discontinuities under conditions when experimental data contain no information on electron temperature at the discontinuities. The application of this method to the measurements revealed that discontinuities ordinarily interpreted as being shock waves will contain $\sim$ 50% tangential discontinuities when there is an increase in flow rate in the magnetic field, or in the concentration and proton temperature.

Direct measurements have shown that the direction of propagation of interplanetary shock waves near the earth depend significantly on the coordinates of

the corresponding powerful chromospheric eruptions (discovered, in particular, was the fact that the fronts of the shock waves inclined to the ecliptic are parallel to the corresponding radius vectors passing through the center of the sun and the eruption). Propagation of the waves in space deviates greatly from spherically and axially symmetrical propagation.

Direct measurements made in the solar wind and by the worldwide network of magnetic stations provided the fact that the effect of the rotational discontinuity of October 28, 1967, consisted of the sudden onset of a magnetospheric storm with an extremely unsteady initial phase (with a characteristic time of ~ 40 minutes). At the same time, it was shown that the brief event of the effect of the front of the discontinuity on the head of the magnetosphere can lead to a very much longer process of establishing a new, steady-state condition in the magnetosphere (than is assumed in contemporary theoretical schemes). Arguments in favor of the fact that this process is the result of the development and damping of the electron cyclotron instability of the external radiation zone were advanced.

G. Further confirmation of the IZMIRAN conclusions that the most geoeffective parameter of the solar wind leading to magnetospheric storms is the southern component of the interplanetary magnetic field, F_s, and its associated characteristics, the eastern component of the electric field of the solar wind, $E_E \approx F_s v$, and the recombination rate for the interplanetary and geomagnetic fields, proportional to $\sim F^2 (1 + \sin \alpha)^2 / \sqrt{n}$ (where n is the concentration, and α is the angle between v and F), was obtained by using as an example the simultaneous measurements made in the solar wind and on the ground between July 5 and 12, 1966. Derived was the fact that the available data from the simultaneous observations point to a substantial correlation between the variations in these characteristics and the indices of magnetospheric perturbability, with a factor of ~ 0.75 to 0.85. /44

Data from simultaneous observations in the solar wind, and in the magnetosphere show that the variation in the southern component of the magnetic field and the eastern component of the electric field of the solar wind are anticorrelated with the energy density of the electrons in the plasma layer of the tail of the magnetosphere and the fluxes, J, of high-energy electrons (> 35 kev) in the zone of unstable radiation. Variations in the fluxes of the recombining

interplanetary and geomagnetic fields correlate with variations in $\mathcal{J}$ in the external radiation zone (at the levels of the most intense changes in $\mathcal{J}$).

H. Analysis of the relation between variations in the geomagnetic field on the earth's surface and in the high latitudes with sector structure and the interplanetary magnetic field, and a comparison of the results thus obtained with the conclusions of certain theoretical papers on the interactions of solar plasma with the earth's magnetic field, led to the conclusion that the penetration of the solar plasma into the magnetosphere near the neutral points on the day side is pulsing in nature.

I. It was established that the development of an auroral substorm will take place during the conception phase, in addition to the known developmental and recovery phases. Characteristic features of the course of a substorm in this phase were recognized in the circumpolar region, and along the oval of auroras. A general planetary scheme for all three phases of substorm development was constructed. Unifying investigation of space-time variations for a series of emissions from the upper atmosphere over the duration of the solar activity cycle was conducted. The general planetary emission energy release in the upper atmosphere during the period of geomagnetic perturbations for an intensity of radiation by hydroxyl and atomic oxygen at a wavelength of 6300 Å was estimated.

J. New data on photochemical processes at various levels in the ionosphere were obtained in the field of ionospheric research, thus posing the reverse problem of the behavior of the neutral components on the basis of data on ion composition. Information on changes in ion formation rates at various heights during the day, during the solar cycle, and with respect to the latitude, was obtained. Some of the work was devoted to the development of special algorithms and to solving the ionization balance equation, the motion and conservation of energy equations, and to other questions. Research on the outer limits and the heat /45
balance of the ionosphere, the beginning of which was laid down as a result of the observations made by Soviet space vehicles between 1959 and 1964, continued. Height profiles of ion concentrations and ion temperature in the upper F region were investigated. Meteorological rockets were used to determine the electron concentration in the D region. Direct measurements were used to construct qualitative models of perturbations in the P region. The connections between ionospheric perturbations and geomagnetic perturbations and the condition of the magnetosphere were studied. An E_s profile that considered all the basic processes was obtained. An E_s layer theory based on the connection between E_s and wind shifts was developed.

III. Investigations of Physics of the Upper Atmosphere and Meteorological Investigations

1. The experimental operation of Meteor, the meteorological space system, continued in the Soviet Union in 1970. /46

Four successive Meteor meteorological satellites were placed in orbit in 1970, in order to ensure the receipt of the meteorological information needed for operational weather service use.

The scientific equipment installed in the Meteor satellites was identical with that installed in the Meteor satellites launched in 1969.

The information supplied by the Meteor satellites was processed in operation sequence and transmitted to the operational organs of the Hydrometeorological Service of the USSR, and to foreign countries in the forms indicated in the National Report of the USSR to the XIII Session of COSPAR in 1970, for practical use in analyzing and forecasting weather, and for scientific research.

The following principal results were achieved during the investigations.

The possibility, in principle, of solving problems of automatic recognition of clouds on photographs of the earth from an artificial earth satellite was pointed out, and programs were written for electronic computers solving this problem as applicable to Meteor infrared photographs.

A scheme for making an objective analysis of the geopotential field at the 500 mb level, with data on cloud cover obtained from the satellite taken into consideration, was developed. This scheme made possible a significant improvement in the quality of the analysis made of the geopotential at the 500 mb level over regions with a sparse network of aerological stations (the absolute error over the North Atlantic was 2 to 3 decameters). Use of this refined analysis improved the quality of the forecast in a number of cases.

The effectiveness of the use of satellite data on cloud cover in an objective analysis of the wind field at earth levels of 850, 700, 500, and 300 mb, was evaluated, and showed that in regions with sparse networks of aerological stations the use of satellite information significantly improves the quality of the analysis made of the wind field.

Previously developed schemes for an objective analysis of the field of isobaric tendencies were the basis for the development of a scheme for making an objective analysis of the dewpoint deficit field, with the inclusion of observations of cloud cover made by the satellite. Consideration of the first examples indicates that the use of data on cloud cover from satellites for making an analysis of the humidity field in regions with a sparse network of weather stations has promise. /47

Recommendations for the use of cloud cover data in synoptic analysis and weather forecasting were made on the basis of theoretical and empirical investigations.

A scheme for determining the upper limit of clouds was prepared, tested under operational conditions, and forwarded for introduction. The scheme can be used during the operational processing of measurements made by the Meteor satellites.

Models of cellular convections in flow with vertical shift in the wind, and in the presence of vortex motion, providing a qualitative explanation of the mechanism involved in the formation of open and closed cloud cells, as well as the cloud banks observed from satellites, have been developed using the approximate solution of nonlinear equations of hydrodynamics as the base.

A scheme for a short-term (up to three days) forecast of the geopotential and the wind at six levels for a good part of the northern hemisphere, with the radiation heat flux taken into consideration, has been developed, and the preliminary calculations in terms of the adiabatic variant of this scheme have shown that the success of the forecasts thus made are entirely satisfactory.

The experiments have shown that the radiation heat flux has a noticeable effect on change in the geopotential at various levels (to 4 to 7 decameters in three days).

Data on the statistical structure and the geographic distribution of integral long-wave radiation have been obtained by Meteor satellites.

A method for determining the temperature of the ocean surface, the total moisture in the atmosphere and the water in clouds, was developed from data measured in the microwave section of the spectrum (wavelengths 8.5, 1.35, and 0.8 cm, and 1.6 mm).

The results of radiometric measurements by Kosmos-243 have been analyzed, and preliminary recommendations for the use of these data in synoptic analysis have been forwarded.

Investigations of the possibility of indirect sounding of the atmosphere by using the measurements made by satellites of radiation field characteristics have been made. The present status of the theory of solving inverse problems of atmospheric optics has been analyzed, and consistent methods for use in solving them have been proposed. Voluminous numerical experiments have been carried out to ascertain the possibilities of accuracy in the reconstruction of the temperature profile in the earth's atmosphere. /48

Data from real satellite measurements of radiation in the 15-micron CO_2 band have been interpreted, and vertical profiles of temperature accurate within 2° to 3° have been obtained.

The possibilities of reconstructing the humidity profile in the earth's atmosphere have been studied.

Calculations have been made to determine the optimal conditions for measurements in the problem of thermal sounding of the atmosphere.

2. The satellites Kosmos-320 and Kosmos-384 were used to continue the investigations begun by Kosmos-149 and Kosmos-243 of the earth's surface, atmosphere, and cloud cover from measurements of the solar radiation in the visible and near infrared regions of the spectra, as well as in the far infrared and radio bands, reflected from the earth. Narrow-angled telephotometers and radiometers, the sensitivity of which could be monitored in flight, were installed in Kosmos-320 to determine the height of the cloud cover, h, by making simultaneous measurements of reflected solar radiation in the 0.76 micron oxygen band and natural radiation from the clouds in the 10.5 to 11.5 micron "transmission window" (the root-mean-square error in determining h was about 1 km). Based on these measurements, and under cloudless conditions, the temperature of the ocean surface was determined with a root-mean-square error of about 2°. Kosmos-320 also measured the earth's integral radiation flux, and the reflected solar radiation.

Synchronized measurements in the infrared and radio bands by Kosmos 384 established temperature and surface conditions, as well as cloud cover parameters.

3. The results of a comprehensive complex of SHF radiometric measurements were the basis for calculations ensuring the selection of the optimal parameters for SHF scanning radiometers designed to determine ice zones and regions of rainfall from the satellite.

Corresponding calculations were made for various sighting angles for a water surface, and for dry and wet ground (Figure 23, a, b). The 8-mm band was shown to be the most advantageous for solving these problems, considering the need to obtain high angular resolution.

Measurements of the characteristics of infrared radiation in the 8 to 12 micron band by precision radiometric equipment showed that the role of the aerosol evidently is minor in a cloudless atmosphere. This follows from the fact that the results of the calculations for the descending radiation fluxes, made without the aerosol taken into consideration, and the data from the experiments are in good concordance. /49

Extensive experimental data on the coefficient of blackness, γ, of the clouds in the upper (γ= 0.05 to 0.38) and middle (γ = 0.45 to 0.85) layers were used to evaluate the accuracy with which the temperatures of the underlying surface in the 8 to 12 micron band are measured when the corresponding forms of cloud cover are present.

4. The ion composition of the atmosphere was investigated in 1970 at heights greater than 100 km in the middle latitudes and on Hayes Island (Franz Josef Land) using radio-frequency mass spectrometers installed in MR-12 rockets. A wide spectrum of ions, H^+, N^+, NH^+, O^+, OH^+, OH_2^+, OH_3^+, N_2^+, HN_2^+, NO^+, HNO^+, O_2^+, and others was obtained. A very sharp change, by more than one order of magnitude, in the concentration of basic ions under comparatively quiet geomagnetic conditions was recorded in the polar region as compared with that observed in the middle latitudes. No significant changes in spectral composition of the ions was found, however.

Electron concentrations, and the electron temperature in the ionosphere at heights up to 170 km, were investigated by a cylindrical Langmuir probe and an impedance probe. Rockets were launched in the middle latitudes in the summer of 1970, when the sun's zenith angles were between 90° and 100°. It was found that at zenith angles near 100° the electron temperature is close to that of a neutral gas at heights greater than 140 km. At lesser heights the electron

temperature, T_e, is significantly higher than the neutral gas temperature, T_n, with the difference $T_e - T_n$ changing from day to day. This points to the need for the existence in this particular region of the ionosphere of certain additional electron heating sources of variable intensity. Height profiles of electron concentration also were obtained when E_s layers were present in the ionosphere. One experiment recorded a sporadic E layer, the maximum electron concentration in which was in excess of the background concentration by a factor of approximately 1000.

Artificially illuminated clouds were used in 1970, to continue the study /50
of the physical characteristics of the upper atmosphere. MR-12 rockets carrying containers of various reagents to form artificially illuminated clouds were launched from Hayes Island in February-March 1970. The work was carried out under the terms of the agreement on Franco-Soviet scientific cooperation. The purpose was to study temperatures, winds, and diffusion in the upper atmosphere in the polar region. Soviet and French experts measured the temperature from the absorption of resonant radiation from sodium. These measurements were made on the ground and the results confirmed the conclusions arrived at after the 1967-1969 experiments involving the presence of a seasonal effect and sporadic variations in temperature. The lower thermosphere was not as hot in 1970, as /51
it was in 1969. Preliminary data on temperatures was reported to the XIII Session of COSPAR in 1970, by French and Soviet experts. The basic conclusions on wind and diffusion are as follows. Winds were not as strong at heights up to 164 km during the period indicated. There were but two cases of velocities slightly in excess of 100 m/s. Velocities were less in all the other /52
cases. Velocities of 150, 200, and even 300 m/s, had been recorded in previous years. In 1968, for example, there had been unusually rapid wind velocity changes within 24-hour periods.

The diffusion coefficients obtained by processing the photography of the artificially illuminated clouds were in general concordance with other results. They were, however, systematically higher than standard values at heights of about 170 km.

Two MR-12 rockets were launched in the middle latitudes in the summer of 1970, to verify experimentally the theory of the formation of the E_s layer. The noses of the rockets contained instrumentation for measuring electron concentration and electron temperature as well as a container of the material for forming

the long, artifially illuminated trace. Other observation equipment, a meteor radar in particular, for investigating winds in the meteor zone, was used simultaneously. The materials are under study at this time.

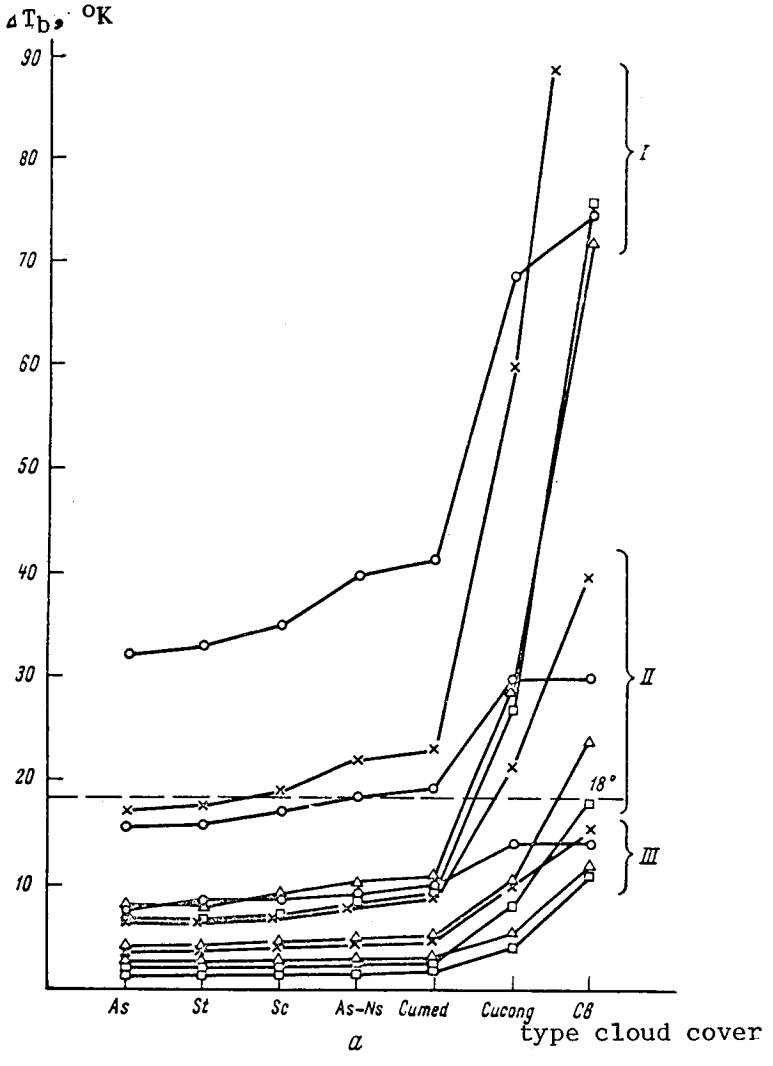

Figure 23. Radio brightness temperature contrast for clouds and precipitation at wavelengths of 0.4, 0.8, 1.35, and 1.6 cm.

a - various cloud forms

I - water surface; II - wet ground; III - dry ground.

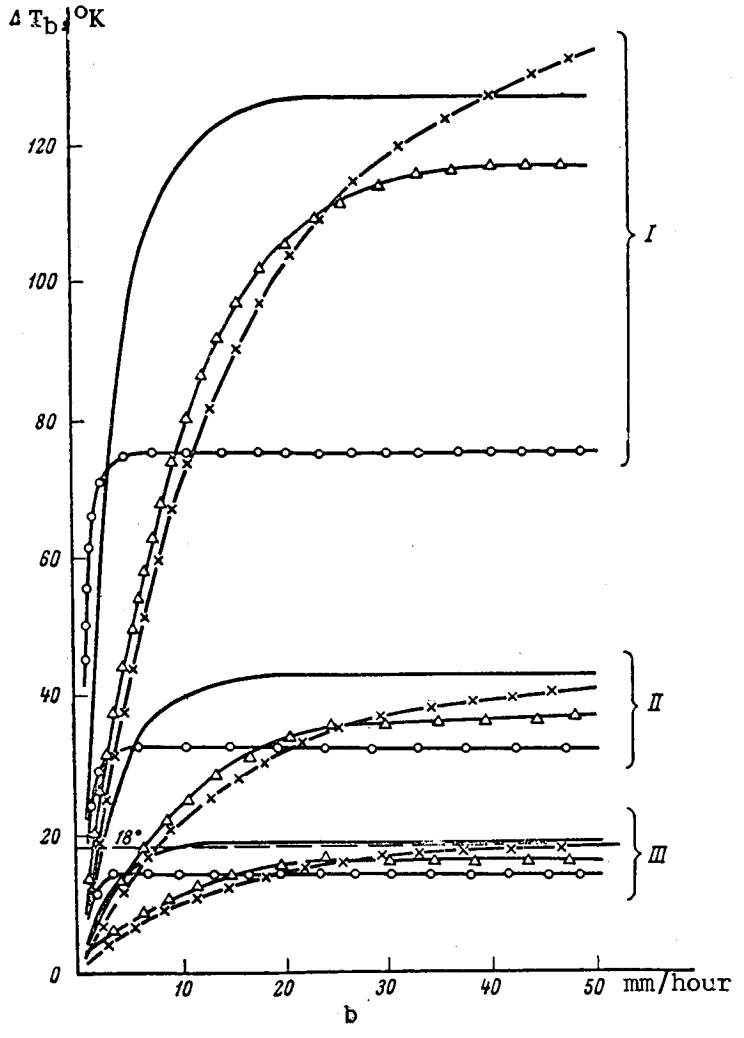

Figure 23. Radio brightness temperature contrast for clouds and precipitation at wavelengths of 0.4, 0.8, 1.35, and 1.6 cm

b - precipitation from 0.1 to 50 mm/hour

I - water surface; II - wet ground; III - dry ground.

The meteor method of investigating winds at heights of about 100 km has been systematically used for many years. Regular observations were made by Molodezhnaya Station in Antarctica, in the Moscow area, and on Hayes Island, in 1970. Analysis of the materials obtained shows that at heights of about 100 km, the zonal wind direction is eastward in both hemispheres for the greater part of the year. A wind reversal is observed in the fall-spring changeover periods. Zonal circulation is more intense in the southern than in the northern hemisphere. The general tendency of the direction of the meridional components

of the wind is to be from the summer hemisphere to the winter. The velocity of meridional flows in both hemispheres is much lower than the velocity of the zonal flows for the overwhelming majority of months during the year. Figure 24 shows the data on zonal and meridional winds for Hayes Island, Molodezhnaya Station, and the Moscow area. Data obtained in Adelaide in 1952-1954 are included in the figure for purposes of comparison.

The tidal circulation in the southern hemisphere is a mirror image of the tidal winds in the northern hemisphere. The seasonal pattern of amplitudes of semidiurnal wind harmonics in the high and middle latitudes has many similar features in both hemispheres.

A good deal of work, laboratory as well as theoretical, was done in 1970, /53 including some on the theory of the motion of meteorite particles in the earth's atmosphere and in deep space.

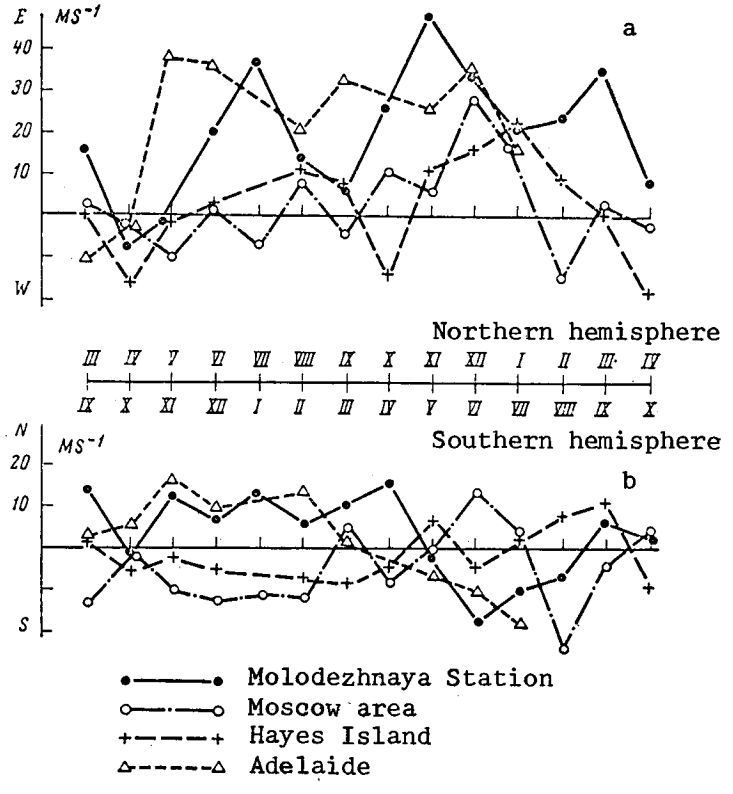

Figure 24, Prevailing winds.

a - zonal components; b - meridional components.

5. Proposals for a new model of the ICAO Standard Atmosphere were developed.

Observations of the movements of the Kosmos series of artificial earth satellites were processed during the period 1964-1970 to determine the density of the upper atmosphere at heights between 160 and 300 km.

Comparison of the results obtained with data from the CIRA-65 and the Yakkia 1970 models yielded satisfactory coincidence of height profiles of night density and its diurnal variations with the Yakkia model (the relative deviation does not exceed 10 to 15 percent, as a rule). Differences were more significant in the case of the CIRA-65 model, where the deviations were from 25 to 30 percent for the period of high solar activity.

Analysis of semiannual variations in atmospheric density showed a significant difference from data from the CIRA-65 and Yakkia 1970 models. A noticeable change in the amplitude of the semiannual variations for the included time interval was obtained. This change does not correspond to the 11-year cycle of solar activity, or to the data from the models indicated above. /54

Longitude variations in the thermobaric field were obtained from mean charts of baric topography for high levels in the northern hemisphere. It was found that maximum variations in mid-winter were commensurate with seasonal variations at the level of the 2 mb surface. Longitude differences are associated with the development of the Aleutian anticyclone in the stratosphere, and with the displacement of the circumpolar cyclone, and show a noticeable decrease in the lower mesosphere.

Circulation patterns in the high layers of the atmosphere have been obtained. The summer circumpolar anticyclonic vortex, like the winter cyclonic vortex, is a stratomesosphere baric formation. The winter anticyclones on the periphery of the circumpolar cyclonic vortex are bounded from above by the 2 to 4 mb surfaces, and are stratosphere formations, for the most part.

An analysis was made of circulation on a global scale, and what follows is that the summer anticyclonic circulation is practically identical in both hemispheres. The winter circulation in the southern hemisphere is not as turbulent because of the characteristics of the underlying surface in this hemisphere.

A round of special rocket measurements of some of the characteristics of the upper atmosphere was made with M-100 rockets fired to 100 km, and MR-12

rockets fired to 170 to 180 km, in addition to the synoptic analysis of the data from the standard rocket probing.

Specifically, some 50 M-100 rockets carrying corpuscular stream sensors were launched from the high-latitude rocket probe station on Hayes Island. Data on the nature and scale of the time variations in the intensity of corpuscular radiation at heights between 80 and 100 km were obtained.

MR-12 rockets, instrumented for measuring the thermodynamic parameters of the upper atmosphere, were launched from Hayes Island and point "Volgograd" in 1970. Data on the vertical distribution of temperature and density were obtained.

Data on temperature between 80 and 115 km are the most interesting. Here the temperature stratification has several maxima and minima, with change in maximum and minimum temperature levels in terms of time taking place out of phase. Of interest as well is the fact that the temperature of the lower thermosphere in the high latitudes is well below that in the middle latitudes. These latter data also are confirmed by the results obtained from the "omegatron" mass spectrometer and the radio-frequency mass spectrometer. /55

Rockets carrying multigrid Langmuir probes and radiation flow sensors for the 5577 Å region were launched at "Volgograd" during sunrise. This provided information on the distribution of ion concentrations and temperatures between 110 and 160 km, as well as data on the flow of scattered solar radiation (zenith angle of the sun $\sim 90^{\circ}$) between 60 and 90 km.

Hayes Island and "Volgograd" continued to measure the composition of the neutral atmosphere by radio frequency (MKh-6407P) and time-of-flight (MKh-5402) mass spectrometers carried by MR-12 rockets, and to process and interpret new results, as well as the 1968-1969 results.

Study of the data from the October 30, 1968, launch from Hayes Island led to the conclusion that the increased concentration of helium recorded during this launch was attributable to the intrusion of extraterrestrial helium, and not to the existence of a winter helium "bulge." The helium intrusion was accompanied by a short, sharp increase in the relative concentration of nitrogen atoms (Figure 25, curve No. 4).

The January 15, 1969, launch from Hayes Island recorded an intrusion into the lower thermosphere of hydrogen atoms of extraterrestrial origin. As will

be seen from Figure 25, the increase in the absolute concentration of hydrogen atoms was accompanied by a considerable rise in the relative concentration of nitrogen atoms (the ratio of ion currents was $J(N^+)/J(N_2^+)$) and by a sharp rise in the relative concentration of hydroxyls (ratio of ion currents $J(OH^+)/J(H_2O^+)$). Readily seen is the fact that the "antiphase" reductions in the absolute concentration of N_2 molecules (ion current $J(N_2^+)$) correspond to the increases in the numerical density of hydrogen atoms (ion current $J(H^+)$) and the "in-phase" increases in the relative concentration of nitrogen atoms (ratio of ion streams $J(N^+)/J(H_2^+)$) at levels of $\sim$ 152 and 128 km (descent).

The two layers of nitrogen atoms detected during the July 25, 1969, launch by the MKh-5402 time-of-flight mass spectrometer, and by the MKh-6407P radio frequency mass spectrometer, also correspond to the two layers of neutral hydrogen atoms.

It is important to note that the data from the ionosphere station of Hayes Island for January 15, 1969, and those from "Volgograd" for July 25, 1969, /57 show that ionospheric perturbations occurred at time coinciding with launch times.

Figure 26 contains the results of measurements made of atomic nitrogen by seven MR-12 rockets carrying radio frequency mass spectrometers MKh-6403M and MKh-6407, as well as the MKh-5402 time-of-flight mass spectrometer. The upper limit of the $J(N^+)/J(N_2^+)$ ratio, obtained from ground laboratory calibrations, was 0.1 for the type MKh-6407 mass spectrometers, 0.12 for the MKh-5402, and 0.03 to 0.05 for the MKh-6403M. This means that high concentrations of nitrogen atoms were observed during practically all launches, over the whole of the territory, or sections of it.

6. Processing of the Kosmos-215 1968 observations was completed in 1970-1971. A two-channel ultraviolet photometer was used to record earthlight in the hydrogen (λ 1216 Å) and atomic oxygen (λ 1300 Å) lines. The observations covered heights from 220 to 420 km, and angles between 30° and 160°, read from the direction to the sun.

The total optical thickness in the center of the L_α line in terms of the solar depression angle within the above-indicated limits was determined by comparing the results of the observations with the calculations of intensity of /58 scattered L_α radiation. Curves of intensity of L_α radiation in terms of height for fixed solar angles, as well as curves of intensity in terms of solar angle for constant heights, were obtained. Variations in L_α radiation with a 27-day

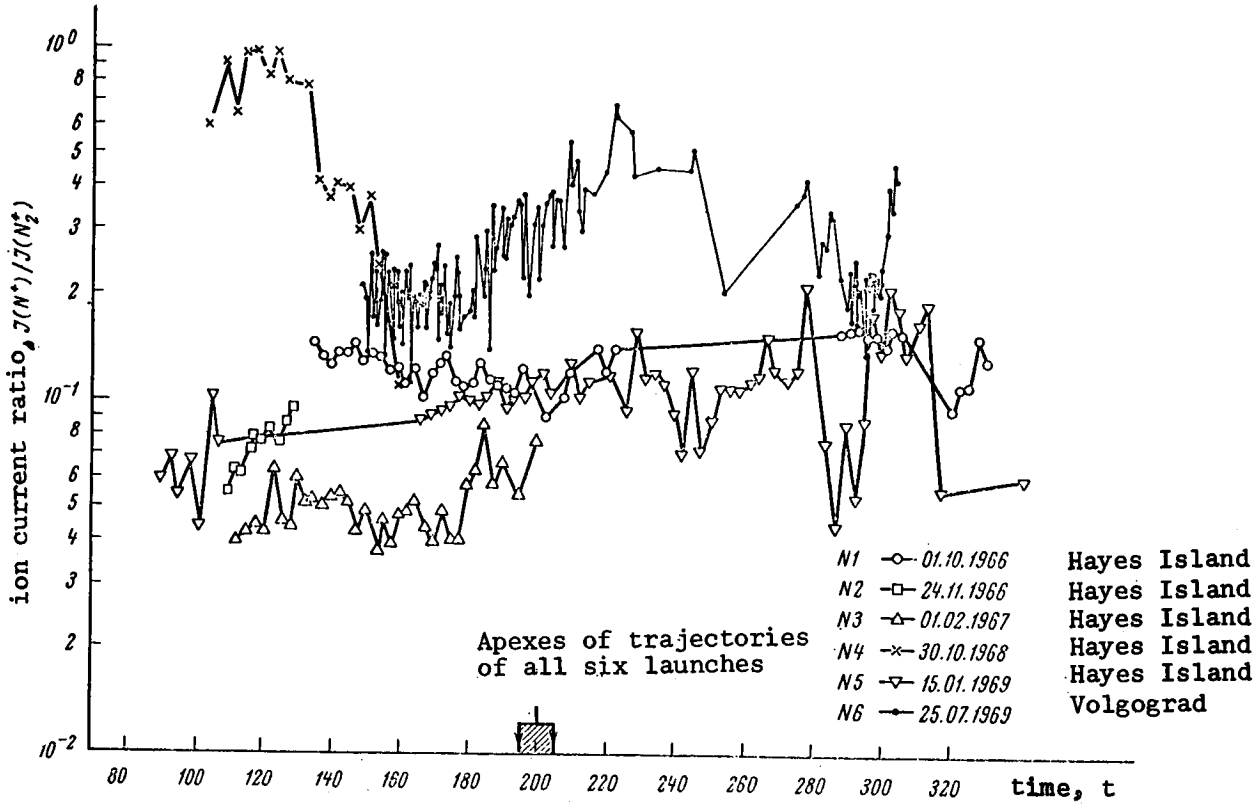

Figure 25. Results of rocket measurements of relative atomic nitrogen content.

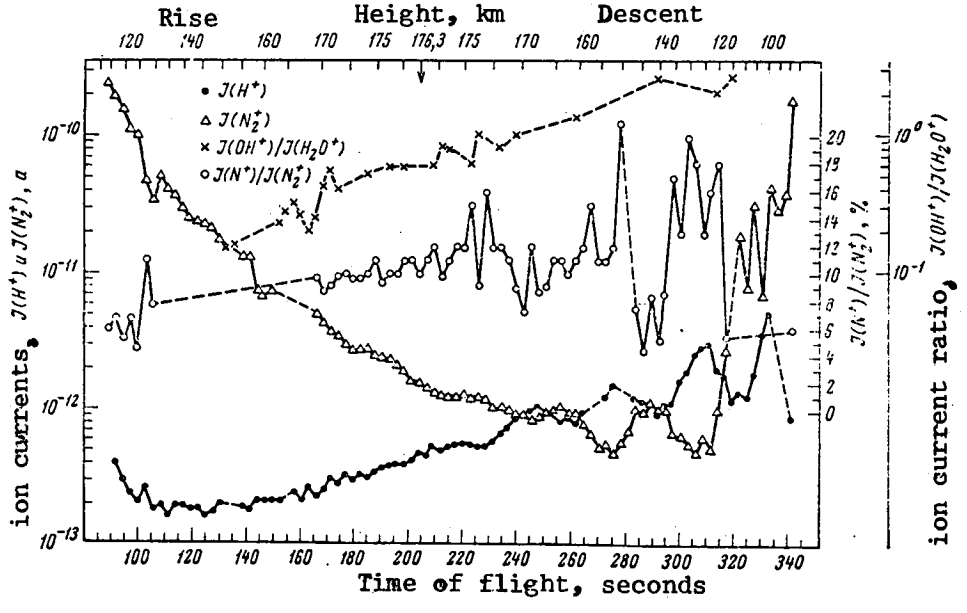

Figure 26. Results of measurements by seven MR-12 rockets of composition of atmosphere .

period, correlating with the indices of solar activity (the number of sunspots, or the solar radio radiation at the 10.7 cm wavelength), were detected. Conclusions were drawn with respect to variations in intensity in the center of emission line L_α, as well as with respect to change in the total number of hydrogen atoms in the exosphere.

Similar curves, as a function of height and solar angle, were obtained for intensity of radiation in the lines of a triplet of atomic oxygen (λ1300 Å). Variations in intensity correlating with solar activity were found.

Night "tropical" radiation in the oxygen lines, observed in regions localized 12° to the north and to the south of the geomagnetic equator, was detected. Conditions for the occurrence of tropical glow in terms of local time were determined. Analysis shows that the most probable cause of tropical glow is the recombination of the ions of atomic oxygen in the region of increased electron concentration.

An experiment designed to measure streams of low-energy electrons during a period of magnetic perturbation, using instrumentation installed in rockets, was successful. The purpose of this experiment was to prepare for the second series of complex "Sun-Atmosphere" experiments (development of procedures and of the work program) planned for 1971, that of rocket probing of the atmosphere during a period of magnetic perturbation and of ground observations of the geomagnetic field and of the ionosphere. Processing the results of the "Sun-Atmosphere 1969" experiment was completed at the beginning of 1970, and preparations were made to publish the materials obtained. This was the first experiment in complex probing of the upper atmosphere during a period of increased solar activity (see the National Report of the USSR to the XII Session of COSPAR in 1969).

New data on the nature of the link between solar activity and corpuscular streams, with ionization of the ionosphere, as well as on the structure of, and circulation in, the lower and upper atmospheres of the earth, were obtained. The results of the experiment were reported to the International Symposium on Solar and Earth Physics at the XIII Session of COSPAR in 1970.

7. Theoretical and experimental research in the field of physics of the high layers of the atmosphere and of space meteorology continued in 1970.

Theoretical research included construction of mean diurnal static models /59
of the atmosphere. The introduction of an average for heat during the diurnal

period for arbitrary solar declination and latitudes succeeded in calculating the latitudinal and seasonal dependencies of the parameters of the atmosphere above 120 km. It was found temperature and density in the middle latitudes have semiannual variations with maxima when the sun occupies one of the equinoctial points. The atmosphere in the middle latitudes is enriched with light components in the winter time. Another important conclusion is that variations in lower boundary conditions in the model in accordance with observed variations lead to substantial variations in parameters throughout the overlying atmosphere. Since solar sources of heating in the middle latitudes provide what is a purely annual rate, it must be thought that the sources of semiannual variations in the thermosphere of the middle latitudes are variations in the parameters of the atmosphere below 120 km.

The development of a theoretical model of the earth's thermosphere was continued. A spatial two-dimensional nonstationary model of diurnal variations in the structure and dynamics of the neutral thermosphere during the equinoctial was calculated.

The results point to a close relationship between the thermal regime and the winds, as well as to the important role of the rotation of the atmosphere at supersonic speed relative to the source of heat, which causes nonlinear effects in wind distribution. Ion friction too has a significant effect on this distribution. Disregarding the influence of the mesosphere, maxima for the diurnal behavior of temperature and density can be observed at practically the same time (15-16 hours).

A methodology for calculating the radiant influx of energy in the upper atmospheres of planets has been developed. Specifically, simple formulas have been obtained permitting an increase by 1.5 orders of magnitude in terms of pressure of layer thickness for the 15 micron band of CO_2, where a convenient approximation of the isolated line is justified in the calculations.

The possibility of the effect on the glow of the mesosphere and of the lower thermosphere of the earth in the infrared band of the spectrum of the radiation from O_2 excited by oscillations in chemical reactions, was studied. It was found that there is little probability of a non-heat glow in the 6.3 micron band of H_2O molecule. The solar radiation absorbed by the 4.3 micron band of CO_2 apparently is completely transformed into heat because of the absence of reradiation of part of the energy in the 6.3 micron band.

Research was conducted on modeling the absorption of CO_2 in the infrared region at high pressures and temperatures (up to 800°K). The intensities and positions of the lines of the isotope $C^{12}O_2^{16}$ were calculated for a wide array of "hot"transitions, with Fermi resonance taken into consideration. Theoretical calculations were the basis for gaps in the 2 to 20 micron band for CO_2 for high pressures (50 atm) and temperatures (800°K) for the calculations of radiation transfer in the Venusian atmosphere. /60

The feasibility of thermal probing of the atmosphere of Mars at the infrared end of the spectrum was investigated.

Processing the results of the experiments designed to take photography and spectrophotometry of the earth from space by the manned spacecraft Soyuz 6 and Soyuz 7 continued, and a new set of optical experiments with an RSS-2 hand spectrograph was completed.

An experiment involving the simultaneous spectrophotometry of the underlying surface from Soyuz-9 and from an aircraft was carried out, and a wealth of material on the spectral characteristics of various types of underlying surfaces in different parts of the globe was obtained.

Observed for the first time during night observations of the horizon was a thin, uniformly luminescent layer in the form of a braid, equidistant from the earth's surface at an angular distance of 3°39'10". The effect of symmetrically located colored "whiskers" was observed for the first time.

The absorption of CO_2 at pressures up to 25 atm in the 2 to 20 micron range was investigated under laboratory conditions.

Laboratory investigations of the processes involved in the deactivation of excited conditions by collisions in those cases of interest to the physics of the upper atmospheres of planets continued:

(a) the time of oscillatory relaxation of CO_2 (oscillation ν_3) was measured by the optical-acoustic effect method, of importance for radiation transfer in the 4.3 micron band for CO_2;

(b) the cross-section of deactivation of the condition of atomic oxygen, O^- and O, upon collisions with O_2 was measured in a gas discharge, significant for the theory of the composition of the upper atmospheres of planets.

The solar constant, and its variations, were measured using high-altitude balloons. The value K = 1.94 cal/cm^{2}min was obtained. This value can change

by from 2 to 2.5 percent toward the low side, depending on solar activity.

The analysis of all published experimental data on measurements of the neutral composition of the atmosphere by meteorological rockets led to the conclusion that at heights of from 150 to 200 km the ratio of atom to molecule concentrations ($[O]/[N_2]$) decreases from day to night. Analysis of the behavior of ion concentrations resulted in finding similar behavior in the ratio of concentrations of neutral atoms and molecules. Thus, at the heights indicated, the relative share of atomic oxygen is greater in the daytime than at night (the amplitude of the diurnal variations in $[O]/[N_2]$ can be a factor of 2 when activity is low, and 1.5 when activity is of average intensity), something that contradicts present postulations based on purely theoretical models. /61

8. An aircraft fitted out as a laboratory was used to make an experimental investigation of the radiation characteristics of the atmosphere. The results posed, and answered, the question of the possibility of determining radiation characteristics, as well as certain meteorological characteristics (such as temperatures of underlying surfaces and of the upper limits of cloud cover, vertical distribution of temperature, and moisture in the air), from measurements of drifting radiation in various spectral intervals by artificial earth satellites.

A methodology for calculating spectra of ascending and descending longwave radiation for sections of the spectrum between 3 and 40 microns with a spectral resolution of 0.1 micron was developed. This methodology then was used to calculate spectra of drifting longwave radiation for a broad set of atmospheric stratifications characterizing the various regions of the USSR at different seasons of the year. The availability of a great many calculated spectra for diverse meteorological conditions in the atmosphere leads to the solution of certain problems of importance for satellite meteorology.

The spectral calculations were used to obtain the possible magnitudes of radiation contrasts for cloud cover at various levels (optical parameters of the cloud cover taken into consideration) against the background of the underlying surface, in order to solve the problem of interpreting the infrared images of cloud cover from artificial earth satellites. Conclusions were drawn as to the advantages of measurements being made in the 3.5 to 4 micron band, as compared with those made in the 8 to 13 micron band. The magnitudes of the radiation

contrasts usually are 1.5° to 2.5° larger in the former transmission window than they are in the latter.

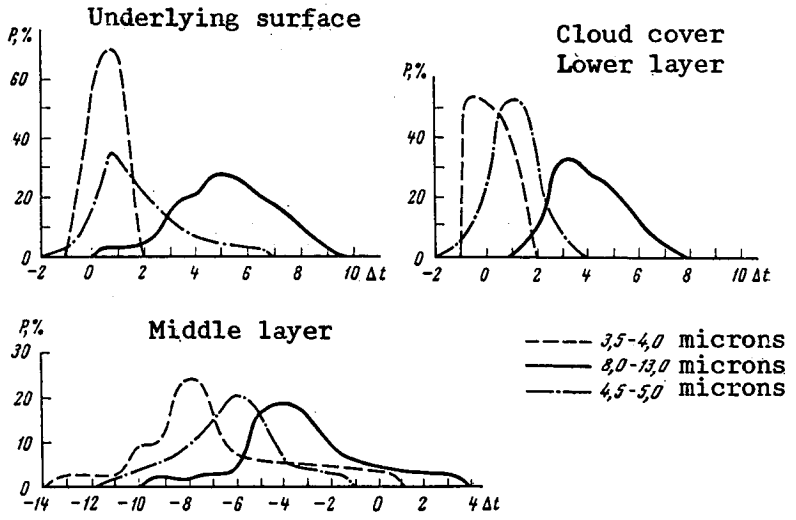

Figure 27. Probabilities of the distribution of errors for the underlying surface for the lower and middle layers over the USSR.

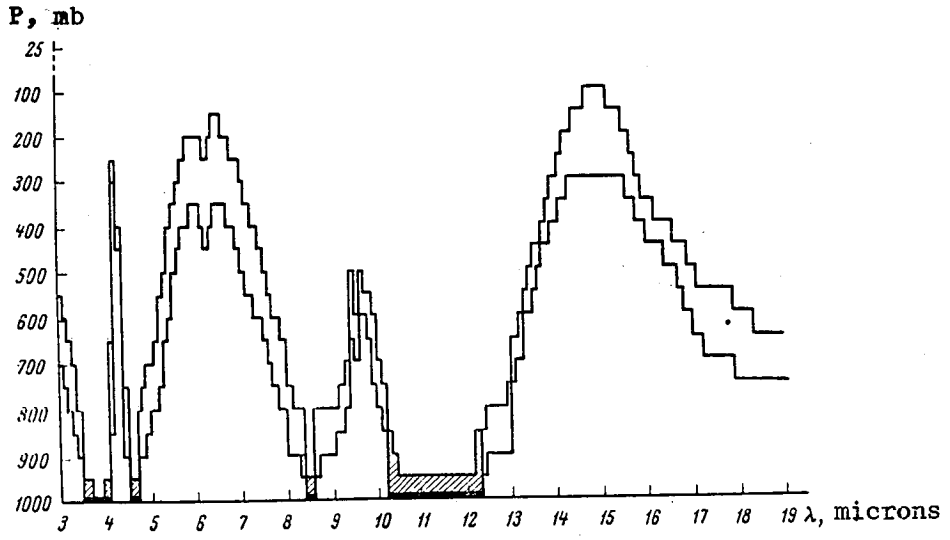

Figure 28. Statistical spectral relationships between the intensities of drifting radiation and actual temperatures in the atmosphere.

The evaluations made of the influence of the various factors (radiation characteristics of the underlying surface and cloud cover, spectral and angular characteristics of the measurement system, scanning angles, and others) on the magnitudes of radiation contrasts for cloud cover resulted in obtaining the value of errors occurring when measurements are made by infrared equipment carried by artificial earth satellites. Errors in finding the radiation temperature of the underlying surface and of the upper limits of the cloud cover as a result of the absorption of infrared radiation in the atmosphere were calculated. Figure 27 shows the probabilities of the distribution of these errors for the underlying surface and cloud cover for the lower and middle layers over the USSR. The calculated spectra were used to find the statistical spectral relationships between the intensities of the drifting radiation and the actual temperatures in the atmosphere (Figure 28). /63 The empirical relationships obtained were used to develop a methodology for the restoration of vertical profiles of temperature and moisture in the atmosphere. The restoration method is based on iteration of the solution of the direct transfer problem.

A methodology for restoration of the profile of moisture in the atmosphere from measurement of the spectrum of drifting radiation in the water vapor absorption band was developed. The result of solving the problem was finding that the unknown parameters could be expressed in terms of certain integrals readily calculated with an electronic computer.

The methodology thus developed makes it relatively simple to determine the profile of the moisture in the atmosphere.

Recommendations for actinometric radiometer design were obtained.

Analysis revealed that the use of the existing standardization system, designed to prevent degradation of instrument response, is ineffective.

It was shown that a systematic error can be found by processing measurements of longwave radiation over selected ocean areas, or by studying climatic distribution of longwave radiation.

Certain of the errors in the interpretation of satellite measurements on longwave, as well as shortwave, channels were reviewed, and instrumentation developments aimed at determining spectral indicatrices of reflection, and of spectral albedo, from an aircraft, were described.

IV. Optical Observations from Artificial Earth Satellites

/64

The Soviet Union is actively engaged in making optical observations from artificial earth satellites for purposes of satellite geodesy and investigations of the structure of the upper layers of the atmosphere.

Data on observations made in Bulgaria, Hungary, the German Democratic Republic, Cuba, Mongolia, Poland, Rumania, Czechoslovakia, England, Holland, the United Arab Republic, France, Finland, Sweden, and in other countries, are received regularly by the Astronomical Council of the Academy of Sciences of the USSR and the "Kosmos" Computer Center. The "Kosmos" Center has issued 124,563 ephemerides to stations in the USSR, and 22,228 to stations in cooperating countries. It has received 16,205 observations from Soviet stations (16 percent) and 1,021 observations from stations abroad (5 percent).

The largest number of observations was made by the Soviet stations in Yeniseysk (No. 1078), Novosibirsk (No. 1035), Odessa (No. 1036), Ryazan' (No. 1042), and by stations in the German Democratic Republic and Hungary.

The observations made by the satellites Polyot-1 (6343-1), Samos-2 (6101-1), Explorer-39 (6644-1), and Explorer-19 (6353-1) to investigate oscillations in the density of the upper atmosphere, continued in 1970. The work of simultaneous investigation of changes in the periods of revolution and rotation of the same satellite continued (Odessa Astronomical Observatory, Astronomical Council of the Academy of Sciences of the USSR).

The Astronomical Council of the Academy of Sciences of the USSR, in collaboration with the socialist countries, drew up a future plan for cooperation in the field of investigation of variations in the deceleration of artificial earth satellites in the upper atmosphere between 1971 and 1975. Preparations were made for taking highly accurate photography of satellites for upper atmosphere research. Stations in the USSR, and in the cooperating countries, will participate in making the observations. They will use the AFU-75 Soviet camera, and the German SBG camera. This will solve the problem of building a model of the atmosphere that will take into consideration brief oscillations in density through the use of analytical theory, and of investigating changes in the atmosphere's rotation rate.

The Astronomical Council of the Academy of Sciences of the USSR is continuing its organizational work based on bilateral agreements for new stations in /65

Africa and Asia, and the equipping of these stations with the AFU-75 Soviet camera. This camera now is installed in Helwan (United Arab Republic), Afgoi (Somali Republic), Ulan-Bator and Delan-Dzagdad (Mongolian People's Republic), Kerguelan Island (France), Dodaira (Japan), Fort Lamy (Republic of Chad), Khartoum (Sudan), and Santiago de Cuba (Cuba). AFU-75 cameras have been installed in stations in Bulgaria, Hungary, the German Democratic Republic, Rumania, and Czechoslovakia.

Soviet stations making photographic observations of satellites during 1970 participated in several international programs of observations for purposes of satellite geodesy, including the following.

1. The Astronomical Council of the Academy of Sciences is coordinating the work being done on the "Vector Motion, Arctic-Antarctica" project by the East European "Satellite Geodesy" Subcommission. An experimental session of synchronized observations of the Pageos satellite was held in April-May. Synchronized films were obtained by the stations in Uzhgorod (74), Zvenigorod (131), Helwan (167), Afgoi (223), Yuzhno-Sakhalinsk (4), Kerguelan Island (11), Mirnyy (11), and Ulan-Bator (4).

2. The first observations under the "Dinamika" program were made in the spring of 1970. All Soviet and foreign stations with the AFU-75 camera took part. Targets of the observations were nine geodesic satellites in different orbits. The program is designed to last several years and is being coordinated by the Astronomical Council of the Academy of Sciences of the USSR.

3. Stations under the Astronomical Council of the Academy of Sciences of the USSR are taking part in the "International Experiment in Satellite Geodesy" program (ISAGEX), which is being conducted as a result of the resolutions adopted by the XII and XIII sessions of COSPAR. The experiment will last until July 1971.

Some 500 negatives from the satellites Midas 4, Geos A, Geos B, VYeV, and Pageos, were obtained during the period of preliminary observations under the ISAGEX program (September-October 1970).

Electronic computer programs for astrometric processing of the negatives obtained by the AFU-75 camera were utilized in 1970, in the Astronomical Council of the Academy of Sciences of the USSR, and by the Riga satellite observation stations.

These programs were used to calculate the experimental coordinates for the Pageos satellite, using materials from the international observations session, "Europe-Africa," obtained by Soviet stations. In accordance with the understanding, all results (244 negatives) were forwarded to the coordinating center, the Geographic Institute of France. /66

Theoretical research in the field of satellite geodesy is in progress in the Soviet Union. Procedures have been developed, formulas have been derived, and a set of computer programs has been compiled for calculating lengths and directions of earth chords from photography and laser observations of satellites. The first results have been obtained for the Riga-Uzhgorod chord from observations of Geos 1 flares, and for the San Fernando - aux Province chord.

Also under development is a procedure for determining the lengths and directions of earth chords from simultaneous Doppler and photographic observations of satellites. Research has been conducted on the influence of the motion of the earth pole on the results of astronomical observations, including satellite geodesy.

A program for calculating the coordinates of ground stations by the orbital method has been perfected.

The Bucharest Observatory is working with the Astronomical Council of the Academy of Sciences of the USSR to determine the azimuths of chords and the coordinates of stations from the results of observations made by Soviet stations.

Methods for determining the quasinodical periods of revolution of satellites from observations by the AFU-75 camera are under investigation jointly with Hungary.

Regular publication of the results of optical observations of satellites for purposes of investigating the upper atmosphere is continuing.

The X Scientific Conference of Scientists of the Socialist Countries on Questions of the Scientific Use of Satellite Observations was held in Bucharest in July 1970, as part of the Interkosmos Program. Guests participating in the conference included representatives of England, France, Finland, and the United States, a total of some 70 participants.

Two meetings of the "Laser-Radar" Working Group were held in 1970, the first in April, in Prague, the second in November in Uzhgorod.

The work program of this group envisages the building of a satellite laser rangefinder within the terms of cooperation between the socialist countries. The Czechoslovakian Academy of Sciences is coordinating the work.

As in previous years, there has been a regular exchange of experts between the Soviet Union and the cooperating countries for mutual consultations and for carrying on joint scientific work.

V. Medical and Biological Research

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1. In-flight investigations. The Soviet Union's Soyuz-9 spacecraft flew a successful 18-day mission between 1 and 19 June, 1970. The spacecraft carried a two-man crew, Commander A. G. Nikolayev and Flight Engineer V. I. Sevast'yanov. As is customary, the functioning of the cardio-vascular system, respiration, energy expenditure, condition of the central nervous system, and analyzers were studied, and certain biochemical indices were photographed. The dynamics of the capacity to work was investigated using data on how work was performed, and from a series of special probes.

The flight took place precisely as programmed. The parameters of the microclimate in the living spaces in the spacecraft remained within permissible limits. Radiation conditions during the flight were favorable. A. G. Nikolayev experienced but 0.316 rad, and V. I. Sevast'yanov 0.397 rad of irradiation.

The cosmonauts ate four times a day. The daily ration contained a mean of 2700 kcal. The food intake program envisaged a requirement of about two liters of liquid a day per man.

The cosmonauts twice a day during the flight did a set of physical exercises designed to offset the unfavorable effects of weightlessness.

The increase in pulse and respiration rates during the prelaunch period was natural for such a situation.

Once the spacecraft was in orbit, and by the sixth revolution, the heart beats approached those recorded a month prior to launching. Pulse rate continued to drop. By the third day into the flight it had dropped 8 to 10 beats/minute in terms of the background in the case of A. G. Nikolayev, and 6 to 13 beats/minute in the case of V. I. Sevast'yanov, and stayed at this level until about the tenth day, after which it gradually rose, approaching the level /68 of the background indices. The reaction of the cardio-vascular system to programmed exercises was no different from that found in the ground data when pulse rate and arterial pressure during the flight were compared.

External respiration, gas exchange, and energy expenditure experienced by A. G. Nikolayev were studied during the flight with his active participation.

It was established that there is an increase in pulmonary ventilation and an increase in the vital capacity of the lungs under conditions of relative rest in the weightless state. Analysis of the gas probes showed a greater absorption of oxygen and increased liberation of CO_2, at rest, as well as when doing programmed exercises. Energy consumption increased at rest by 0.86 to 1.03 kcal/min, and by 0.68 to 0.86 kcal/min when exercising.

Both cosmonauts, upon entering orbit, experienced reddening and puffing of the face and the sensation of blood rushing to the head, but this latter sensation decreased sharply by day two.

Analysis of urine collected on the first, second, and 18th days of the flight revealed that excretions of potassium, calcium, sulfur, phosphorus, and nitrogen increased as the flight continued.

Appetite during the flight was normal, the sensation of thirst was somewhat reduced, and urination was regular. There were individual days when the stool was delayed. Sleep for the most part was deep, refreshing, and lasted for from 7 to 9 hours. Mental and physical powers remained at a high level throughout the flight.

The first medical examination after landing found the cosmonauts tired, and definite effort was required to stand erect, so they preferred lying down. Their subjective sensation was one of having heavier than normal bodies. This unique illusion of a heavier body gradually disappeared after about three days.

The at-rest heart beat immediately after landing was about 120 per minute. The short (5 minute) orthostatic test conducted at this time was borne with definite stress by both cosmonauts.

Initial weighings showed that A. G. Nikolayev had lost 2.7 kg, and that V. I. Sevast'yanov had lost 4.0 kg. Noted was a reduction in the fibular tarsal bones and in the bones of the proximal phalanges of the fingers. The optic density of the bones had not returned to its original level by the 22nd day of the postflight period.

The volume of circulating plasma decreased 2 percent in the case of A. G. Nikolayev, and 6 percent in the case of V. I. Sevast'yanov. The content of the total serum protein was reduced.

Expressed disbacteriosis was noted during investigation of the automicroflora of the cutaneous coverings and of the mucous membrane of the nose. /69

The materials obtained from medical observations made during and after the Soyuz-9 flight indicate that it is possible, in principle, for man to work actively in space for 18 days and still retain his mental and physical capabilities. At the same time, the data showed that the process of adaptation to weightlessness, and the subsequent readaptation to ground conditions places a strain on the body's adaptational mechanisms, and that readaptation is more difficult. The development of ways and means to ease this process is an important task of future research in the field of space medicine.

The influence of space flight factors on the seeds of higher plants and unicellular Chlorophyceae were studied during the flights of Soyuz-9 and Zond-8.

The results of experiments with air-dried seeds of Crepis capillaris, Allium fistolosum, and Arabidopsis thaliana showed that the factors involved in both of these flights, in and of themselves, had no influence on germination energy, seed germination, or mitotic index in the root meristem. However, these factors did cause an increase in the frequency of chromosomal aberrations during the Soyuz 9 flight, and the increase was greater the more sensitive the plant is to the effect of the external factors (in the case of onions, to 11.61 ± 1.35 percent as opposed to 0.88 ± 0.51 percent for the control, and in the case Crepis to 1.01 ± 0.16 percent as opposed to 0.18 ± 0.05 percent).

Interesting data were obtained with respect to the modifying influence of flight factors on the effect of chemical mutagens and radiation. Treatment with ethylenimine increased seed death. The entire package treated prior to the flight died, and postflight treatment resulted in a significant reduction in the mitotic index for the test, as well as for the control. In this test variant the tendency was to an increase in the number of chromosomal aberrations (22.65 ± 4.83 percent) as compared with the treated control (13.90 ± 2.32 percent). This same behavior pattern had been noted earlier by L. G. Dubinin and O. P. Chernikov (1970).

On the other hand, flight factors had a protective effect against genetic damage caused by irradiation. Among Crepis this effect was statistically reliable when the seeds were irradiated after the flight (2.92 ± 0.34 percent

chromosomal aberrations for the control, 1.44 ± 0.17 percent for the test) and was missing, for all practical purposes, when irradiation took place prior to the flight (11.36 ± 0.89 percent and 12.45 ± 0.54 percent, respectively). The picture was the reverse in the case of the onions. Flight factors had no influence on the effect of subsequent irradiation (23.14 ± 2.09 percent for the control, 20.95 ± 2.15 percent for the test). There was, however, a /70 significant reduction in the effect of preliminary irradiation (52.84 ± 2.53 percent and 27.12 ± 5.79 percent, respectively).

The experiment with unicellular Chlorophyceae on the Soyuz-9 flight was the first to investigate the effect of spaceflight factors on a developing culture. The culture of chlorella autospores was planted in a mineral agarized medium in special containers fitted with opaque filters. The filters were removed by the cosmonauts after the spacecraft was in orbit. The cells in one container were exposed to light for 24 hours, those in another for 6 days, and those in a third for 14 days during the flight. One container remained covered throughout the flight. The algae were resown in a fresh nutrient medium after landing in order to study the survival rate, mutability, and the dynamics of development in destruction in autospore formation. Analysis of the results failed to show that flight conditions had any effect on any of the experimental variants. However, a slight reduction in the survival rate and an increase in mutableness was noted, as was some suppression of the normal development processes among those cultures that had been in a physiologically active state for most of the flight (exposed to light for 14 days).

The Zond-8 experiment was designed to find out what the effect of a long flight would be on recovery from radiation damage to chlorella cells and on the sensitivity to radiation of the inactive chlorella cultures. As in the case of the Soyuz-9 experiment, there was a slight reduction in survival rate and the appearance of mutableness among cultures subjected to the effects of flight factors. Postflight gamma-radiation of the cells showed an increase in resistance to radiation, and a reduction in mutableness, as compared with the ground control.

2. Ground investigations. The antimutagenous effect of AET (aminoethylisothiuronium), the mutagenous effect in the case of different types of

chronic gamma-irradiation of male Drosophilae, and the mutagenous effect in the case of different types of irradiation of the sex cells of male mice, all were studied in order to uncover individual cases of genetic damage after space flights. Placing hungry males on food containing AET prior to their irradiation with a dose of 1000 r, or placing them on the same food immediately after irradiation, resulted in the total number of induced lethal, or semilethal, sex-linked point mutations remaining the same as those for the control when AET was not added to the food. However, AET does cause a statistically reliable reduction in the percentage of induced lethals with a simultaneous increase in the percentage of induced semilethals. These data can be treated /71
as proof of the phenomenon of incomplete recovery from mutagenous damage during which the potential lethal reacts in the form of a semilethal.

Some increase in the frequency of sex-linked recession lethals and semilethals as compared with that found in the case of acute irradiation in massive doses (calculated per r) was observed in the case of chronic gamma-irradiation of male gametes with a total dose of 60 r at the rate of 0.042 r/m. The effectiveness of chronic and a one-time gamma-irradiation of male gametes in small doses was close. Irradiation similar to this gives the greatest mutagenous effect when acting on the spermatogonium, the sensitivity to radiation of which is particularly high. The result is the mass death of those most sensitive to radiation, and therefore of the most mutable cells when they are irradiated with massive doses, regardless of the rate at which the doses are administered.

Analysis of the frequency of occurrence of reciprocal translocations and dominant lethal mutations induced by X-rays and fast neutrons (1.5 Mev) in the sex cells of mice has shown that the spermatogonium genetically is much less sensitive to radiation than postmeiotic sex cells. The nature of the dose-effect relationship in spermatogoniums and in sex cells differs in later stages. In the case of both types of radiation in the interval of doses in which the yield of mutations in spermatozoids and spermatids increased exponentially with increase in dose, the frequency of mutation in spermatogoniums remained at the same level when the dose was increased to above 400 r of X-rays and 72 rads of fast neutrons, and decreased at higher doses (1800 r and 216 rads).

The relative genetic effectiveness of fast neutrons was identical at all stages of the spermatogonium, about 4.5. Fractionation of the X-ray and fast neutron doses into several sessions changes the yield of mutations in spermatogoniums. The mutagenous effect was weakened when the X-ray irradiation was broken down into low-level doses, and this differed from the effect of the neutron action.

Study of the biological effect of various types of cosmic radiation continued. The inactivating effect of accelerated ions B_{11}^{+2}, C_{12}^{+2}, Ne_{20}^{+4}, and Ar_{40}^{+8}, as well as of gamma-rays of Co^{60} and of protons with energies of 645 Mev on the survival rate of E. coli B bacteria in the range of dE/dx radiations of 2.4 to $3 \cdot 10^4$ Mev-g^{-1}-cm^2, was studied. It was shown that the dependency of the survival rate of cells on the radiation dose is exponential for all types of radiation used. /72

Comparing the biological effectiveness of heavy ions with gamma-radiation when the dose is calculated in units of absorbed energy reveals that the biological effectiveness of heavy charged particles decreases with increase in their dE/dx. However, analysis of the dependency of the cross section of inactivation of bacteria, that is, of the magnitude characterizing the probability of inactivation of the object by the particle, on dE/dx for the radiation shows that the cross section of inactivation increases with increase in dE/dx for the particles to over 1000 Mev-g^{-1}-cm^2, and then tends to level off on a plateau in the case of high values of dE/dx; that is, with increase in linear losses of energy the effectiveness of each heavy particle increases.

Change in the mutation process in seeds irradiated with protons with energy of 660 Mev and with gamma-rays long after irradiation, was studied. Lettuce seeds were irradiated with protons with energy of 660 Mev in a synchrocyclotron and with gamma-rays from Co^{60} in doses of 0.25 to 5.0 krad.

Analysis of the effects that developed immediately after irradiation showed that the protons were more effective than gamma-radiation. Induced mutagenesis increases when seeds irradiated by protons and gamma-rays are stored. Straight-line regressions revealed that the intensity of the change in the radiobiological effect per unit time in irradiated seeds does not depend on the type of radiation, but rather increases with increase in the dose. Analysis of types of chromosomal aberration failed to show any significant difference in the action of protons and gamma-rays.

Dosage relations and RBE coefficients were obtained for protons. The RBE coefficient for protons changes with the dose from 2 to 2.8, using direct effects criteria. There is a significant reduction in the RBE coefficient for protons when irradiated seeds are stored. This is because the radiation damage suffered by the stored seeds irradiated with gamma-rays remains.

The need to know the effects of nonuniform irradiation resulted in investigation of 600 rats in order to study the characteristics of the formation of radiation injury in the rats as a result of the variety of effects of radiation with extreme values of decrease in doses in terms of intensity. The animals were irradiated over a wide range of doses.

There is an optimum height-cerebral dose (160 to 230 rad) at which recovery processes occur at the fastest rate. An increase, or a decrease, in the magnitude of the medullary absorbed doses during nonuniform radiation slows the rate of recuperation. /73

Experimentation established the fact that the nature of the daily change in sensitivity to radiation depends on the animal species and strain. There is, however, a basic behavior pattern; sensitivity to radiation increases during active periods of the day, and decreases during the inactive periods. The survival rate among animals (mice, rats) irradiated with gamma-rays from Co^{60} differed by 50 percent for the same dose, but administered at different times of the day. The daily variations in $LD_{50/30}$ were 293 r for mice, and 100 r for rats.

The experiments with dogs exposed to chronic daily gamma-irradiation continued in 1970. Here the total doses given the animals under conditions simulating galactic radiation in dose rate magnitude were 100, 300, and 600 rem, and for those animals subjected to reirradiation as well, they were 580 and 900 rem. Preliminary analysis of the data points to stabilization of changes in the hematological indices by the third year of irradiation and to an intensification in damage to spermatogenesis.

Some of the dogs were removed from irradiation after three years to observe the progress of recovery processes and the development of long-range consequences. A year after cessation of irradiation there was a gradual recovery in terms of the hematological indices and spermatogenesis, but recovery was not total.

Study of the effects of experimental actions on various systems of the organism, and learning more about the mechanisms of these actions, continued. Studied in particular were the hydrodynamic influences that occur between parts of the vestibular apparatus. Experiments with local caloric stimulation of various parts of the labyrinth, and with abduction of impulse activity from the nerve rami of the laterial and anterior vertical canals, revealed that endolymph flows in the labyrinth can be propagated from the site of occurrence to all parts of the vestibulary apparatus if the stimulus is strong enough. The mechanism involved in the hydrodynamic influences can be represented as follows. It is known that the cupula hermetically seals the lumen of the canal. Caloric stimulation of the smooth part of the lateral canal causes a convection heat flow that tilts the cupula in the ampulla-loop direction. The cupula, upon tilting, displaces some volume of endolymph, and this volume, for a definite intensity of stimulation, is sufficient to cause an ampulla-fugal deviation of the cupula toward the anterior vertical canal. Both cupulae function as synergists, so far as the nature of responses is concerned. It is /74 possible that if the stimuli are strong, and if the deviations are great, a gap can form between the apex of the cupula and the wall of the ampulla, and endolymph leakage can occur. In the case of caloric stimulation of the vestibule, the flow of endolymph will branch and upon entering the anterior and lateral canals will tilt their cupulae ampulla-fugally. The cupulae of the canals function as antagonists so far as the nature of the responses of the nerve units in this situation is concerned.

The results obtained are of interest in analyzing vestibular rections when extremal accelerations are acting on the labyrinth.

Interest in preserving human life in emergencies poses the question of the need to study the influence of different compositions of the artificial gas medium that differ from the normal atmosphere in terms of magnitude of total pressure and partial pressure of oxygen and carbon dioxide on the organism. The possibility of man's stay in a gas environment resulting in hypercapnia, one in which pCO_2 was as high as 40 and pO_2 as high as 159-105 mm Hg, was studied in altitude chamber experiments at normal and reduced barometric pressures (405 mm Hg). The results revealed that the human body can adapt to a five-day stay in a medium in which the pCO_2 reading is 23 mm Hg, and at the same time retain adequate capacity to work.

The first days in a medium with pCO_2 of 30 mm Hg developed distinct changes in the external respiration function, gases in the blood, and acid-base balance, all of which indicated stress on the reserve capacities of the organism. In the days that followed there were signs of adaptation which made their appearance in the form of a reduction in the external respiration reaction and in the oxygen demand, in normalization of the acid-base equilibrium indices, and others. Further increase in the carbon dioxide concentration in the inspired air (pCO_2 38 mm Hg, and higher) caused the appearance of decompensation of the acid-base equilibrium and of considerable respiratory stress (respiration minute volume increased by a factor of 3 to 4, and the respiratory volume increased by a factor of 2 to 3).

Body responses were sharper under the combined effect of hypoxia (pO_2 — 105 mm Hg) and hypercapnia (pCO_2 — 23 mm Hg) than under the effects of each of these factors individually.

The nature of the change in body reactions depended on the CO_2 and O_2 concentrations in the chamber when conditions resulting from a breakdown in the life support system were simulated (rise in pCO_2 at a rate of 3.5 mm Hg and a simultaneous reduction in pO_2 at a rate of 4.7 mm Hg). Greatest changes in the indices were noted at pCO_2 and pO_2 limits (56 and 90 mm Hg, respectively). /75 The minute volume in the dormant state exceeded the original level by a factor of 12 to 13, the tidal volume increased to 2.5 liters, the basal metabolism increased 200 to 291 percent, the pCO_2 in the mixed air breathed rose from 23 to 60 mm Hg, and the pO_2 fell to 90 mm Hg. Under these conditions there were metabolic changes when pCO_2 was between 20 and 25, and pO_2 was between 130 and 120 mm Hg.

Intensive study also was made of the mechanisms involved in the effect of hypoxia on the organism, as such, and in combination with other, extremal, actions.

Central nervous system reactions have been studied in particular detail. The evoked potentials method was used successfully, for example, to establish that the reaction of the acoustic cortex begins to develop under the effects of light hypoxia, 12 percent oxygen in nitrogen.

Noted among animals breathing a gas mixture containing 10 percent oxygen were more significant changes in the nature of the indices studied.

The greatest changes in the nature of the evoked potentials were established when a gas mixture containing 8 percent oxygen was breathed. In this case the latent period was extended by a factor of 1.5, the amplitude of the positive phase was reduced between 22 and 29 percent, and the negative phase between 19 and 26 percent.

At the same time, no significant changes in the evoked potential indices developed in the posterior corpora quadrigemina under the effects of light hypoxia. If there were some deviations, they failed to differ from the original values with any degree of certainty. Reduction to 10 percent in the medium's oxygen content evoked definite shifts in the nature of the indices recorded. First of all, the magnitude of the latent period, which, 30 minutes after the beginning of delivery of the mixture to the chamber increased 12 percent, changed. Further stay of the animal in the hypoxic medium increased this even more. The positive phase of the response paralleled this. Reduction was slight in the first 30 minutes and differed from the original by 6 percent. The magnitude of the amplitude decreased by virtue of the animal being in this gas medium and by 180 minutes the reduction was 28 percent. The magnitude of the negative phase too changed significantly. Within 30 minutes it was 26 percent below the original magnitude.

The use of a hypoxic medium evoking a more severe form of hypoxia was accompanied by even greater shifts. Now the increase in the latent period was /76 40 to 62 percent. Paralleling this was a reduction in the amplitude of the positive and, in particular, of the negative phase of the response. The amplitude of the negative phase decreased 46 to 49 percent in the first 120 minutes.

Experimental results thus indicate that the hypoxic effect evokes a change in the functional state of the auditory system that is directly dependent on the severity of the action. Comparing the results obtained for different auditory system levels, it was found that hypoxia evokes unidirectional, and approximately identical changes, quantitatively speaking, in the cortical structures of the auditory analyzer and in the posterior corpora quadrigemina, and that these changes are expressed in the inhibition of physiological processes.

Advance injection of different doses of hydrocortisone during various stages of hypoxic action normalizes the reduced functional state of the cortical and subcortical structures of the auditory system attributable to hypoxia. However, a 5.0 mg dose of hydrocortisone proved to be the most effective for normalizing the rate of excitation and improving the functional state of the cortical neurons during the various stages of hypoxia, whereas doses of 0.2 and 1.0 mg were most effective in the case of neurons of the posterior corpora quadrigemina. It was found that small doses of hydrocortisone (0.04 mg) caused changes to take place only in the neurons of the posterior corpora quadrigemina, and that it was not until the hormone dose was increased (1.0 mg) that changes occurred in the neurons of the acoustic cortex. On the other hand, in response to hypoxic action, the neurons of the acoustic cortex, in which changes occurred when hypoxia was relatively slight, proved to be more sensitive than did the neurons of the posterior corpora quadrigemina.

Depression in the phospholipid exchange in the brain tissue of rats is found when the organism is subjected to oxygen starvation caused by a reduction in the partial pressure of oxygen in the environment. This depression, as special experiments revealed, is attributable primarily to hypothermy accompanying the oxygen starvation of the organism, and is not directly related to the lack of oxygen in the cells of the brain tissue.

In order to recognize the relative role of each of the factors acting under hypoxic conditions, lack of oxygen in the environment on the one hand, and hypothermy on the other, it was necessary to find a convenient model, one that was lacking in those complex regulatory influences and reactions that occur in the whole organism, for use in studying, separately, and in different combinations, the influence of the factors investigated. This convenient /77
model is brain tissue pulp, which can be incubated in vitro, varying the temperature of the incubating medium, as well as the gas composition of the environment.

There is a clear-cut relationship between the demand for oxygen by brain tissue, the intensity of the phospholipid metabolism, and the temperature of the incubating medium in normal air. The specific radioactivity of the phospholipids increases with increase in incubation time. The oxygen requirement does

not change significantly during the period required for the investigation. Reduction in oxygen in the environment to 8 percent causes no significant changes in oxygen requirement, or in phospholipid metabolism intensity. The relationship between the magnitudes of both indices and the temperature of the incubating medium is retained under these conditions. Reducing the oxygen in the environment to 5 percent is an entirely different matter. There is a definite reduction in oxygen demand and phospholipid metabolism intensity at 37° and 32°C, as compared with the findings in air and in an 8 percent O_2 mixture. The magnitudes of the indices investigated depend on temperature. No differences in oxygen demand, or in the specific radioactivity of the phospholipids during incubation in any of the gas media investigated is found when the temperature of the incubating medium is 27° and 22°C.

The impression created, therefore, is that a definite reduction in temperature, has no effect on the metabolism of brain tissue in vitro, even when there is a four-fold reduction in the oxygen content of the environment.

One facet of the research was a study of content and metabolic intensity of the various fractions of phospholipids in the brains of rats during events that change the functional state, or the metabolism of nerve tissue. Selected for these events were hypoxic hypoxia and insulin hypoglycemia, leading to a definite suppression of metabolism and functional activity on the part of the brain tissue due to an inadequate supply to the brain of the main sources of energy, oxygen and glucose, and stimulation of the skin with electricity, leading to the development of definite excitement among the animals. Definite changes in the intensity of the exchange between the phospholipid fractions investigated were observed during all events studied.

The nature and directivity of the changes in metabolism intensity clearly correlated with the nature of the changes in the functional condition of the central nervous system during these events. Metabolism intensity diminished during hypoxic hypoxia and insulin hypoglycemia, whereas there was a proven in- /78
crease during electrical stimulation of the skin.

Male rats were housed in an altitude chamber with reduced partial O_2 pressure for the hypoxic hypoxia experiments. It was shown that a two-hour stay at an "altitude" of 8700 meters was accompanied by a definite increase in

the RNA content of Purkinje's cells of the cerebellum, and in their glial satellite cells, as well as in the motor neurons of the anterior horns of the spinal cord (but not in their glial cells). Some of the rats were also subjected to the intermittent effect of hypoxia. The RNA content of Purkinje's cells, and of their glial satellite cells increased, but the intermittent effects of hypoxia (5 to 5.5 hours daily for two weeks with gradual increase in "altitude" from 3000 to 7000 meters) were no different from the norm by the end of continuous effect (for three weeks at an "altitude" of 5500 meters). On the other hand, an increase in RNA content in the motor neurons of the spinal cord increased only as a result of continuous effect of hypoxia. Thus, the same hypoxia conditions can cause different neuron changes that differ in their functional properties.

Also shown was the fact that acetylcholine apparently can emerge as the protector of intracellular metabolism of RNA in nerve tissue during hypoxia.

Experiments with hypokinesis, using male white mice and male rats individually caged for two or three weeks so as to limit greatly the scope of movement on the part of these animals, were conducted. It was found that RNA in the cytoplasm of the motor neurons of the anterior horns of the lumbar enlargement of the spinal cord, in the body of their glial satellite cells, and in the cytoplasm of the neurons of the sensory spinal ganglia, was not significantly different from the norm by the end of the experiment. RNA in the glial cells of the spinal ganglia increased by the end of the second week of hypokinesis, and decreased by the end of the third week. When the animals were moved to ordinary conditions of mobility there was a definite drop in RNA in neurons, as well as in the glial cells of the anterior horns of the spinal column and spinal ganglia, in the first 2 to 6 hours. This was followed by phase changes in RNA content. These changes were different in neurons and glia and unlike in the motor and sensory regions of the spinal cord. The final return in RNA to the norm did not occur until three days after discontinuance of hypokinesis, and this was the case in the neurons of both regions. Thus, long periods of hypokinesis lead to the adaptation of RNA metabolism in the nervous system under these conditions. The return of the organism to normal motor activity causes many biochemical changes to take place in the nervous system, encompassing all /79
the basic types of the system's cellular structures.

Study of the effect of a combination of hypokinesis and hypoxia involved caging the rats and placing the cages in an altitude chamber for three weeks. The initial "altitude" was 3000 meters. Then the "altitude" was increased daily for seven days by from 500 to 1000 meters, with the animals then held at an "altitude" of 7000 meters for 14 days. As compared with the control (rats kept in spacious pens and engaged in ordinary motor activity), the animals subjected to the effect of hypoxia alone showed an adequate RNA accumulation in the cytoplasm of the motor neurons of the lumbar enlargement of the spinal cord. There was an even greater increase in cytoplasmic RNA under the effect of hypokinesis alone. The combination of the two also resulted in RNA accumulation, but to a lesser extent than when hypokinesis alone was in effect. Not to be precluded is the fact that hypoxia, while reducing the general intensity of metabolism in the nervous system, at the same time hampers the development of sudden changes in the ratio of synthesis and decay in RNA under the influence of hypokinesis.

One of the important extremal factors in astronautics can be total sleeplessness, or deprivation of sleep's paradoxical phase over a comparatively long period of time. Experimental study of the consequences of long periods of sleeplessness found that the latter causes a consumption of protein in the crucial structures of the mid-brain that is not compensated for by biosynthesis, and that inhibition of higher nervous activity during "narcotic sleep" does not lead to the recuperative processes that take place during natural sleep.

The mechanisms involved in heat regulation under normal conditions, and under certain experimental conditions, were studied.

Among animals, even a relatively small reduction in the oxygen in the air upset heat regulation and showed up in the form of a reduction in the protective reaction to cold (cold muscular tremor, heat-regulated muscular tone). A direct inhibition of the activity of the neurons of the heat regulation center among animals breathing a mixture of gases containing a reduced oxygen content was found. These neurons are much more sensitive to the blood's oxygen content than are the neurons of the cerebral cortex.

The most infrequent changes in heat regulation occur when a mixture of gases containing helium is breathed. Helium has a definite cooling effect and

results in protective reactions to cold even when the temperature of the medium is comfortable. The strong cooling effect of helium mixtures appears in particular in the respiratory tract. /80

Experiments designed to compare one-time, and repeated stress on membrane digestion, the effect of heat in particular, were conducted in 1970.

The membrane digestion factors investigated were the invertase and dipeptidase activity of the surface of intact intestinal sections 2 cm long, and of the homogenates of these same sections 4, 24, 48, and 72 hours, and six days after the last heat was applied.

Significant, and definite, differences in the reactions of the digestive system, and in particular in the reactions of membrane digestion, were found among the animals subjected to one-time and repeated stresses.

These effects are increasing reactions in the case of the former, and decreasing in the case of the latter, as compared with the base. It is interesting to note that systems that react but slightly, or that do not react at all, can be drawn into the reaction when stress conditions are repetitive in nature.

Research along the following lines was conducted as concerns the problem of the physicochemical synthesis of food products:

selection of the optimal schemes for the physicochemical transformation of the products of human activity into carbohydrates, into monosaccharides;

search for new, heterogeneous catalysts for the synthesis of carbohydrates from formaldehyde.

A number of new, previously unknown catalysts were found. They are hydroxides of rare earth elements yielding synthetic carbohydrates, monosaccharides from formaldehyde.

Chromatographic analysis shows the chemical composition of the artificial carbohydrates to contain pentose and hexose.

The results of experimental investigations directed at the psychophysiological analysis of human tracking reactions include certain significant behavior patterns in teaching how to react, and how these reactions take place. They are a reflection of the information processes involved in processing data

on the properties of the demand signal, of the results of natural movements, and of their concordance.

A sequence in the understanding of the individual properties of a regular signal in the teaching process, and the subsequent synthesis of those properties in the form of a motor program, was found.

The construction of a motor program is the basis for forecasting near-time changes in the demand signal so that control can be exercised without delay. /81

Two methods of regulating man's natural tracking movements have been found:

regulation of frequency under tracking conditions when changes in the demand signal are rapid;

regulation of the rate under tracking conditions when signals are moving slowly.

The advantages of position tracking of the movements of a bright spot on a cathode ray tube, as compared with a number of other types of tracking (compensatory tracking, tracking indicator needles, derivative tracking), were developed and analyzed.

Errors in, and time characteristics of, discrete tracking were analyzed. It was found that the influence of programming actions in the central nervous system on the selection of the next movement was significant.

Research on the functional characteristics of biological systems continued. This research can be the basis for designing the complex of life support equipment needed under the conditions prevailing on long space flights.

Study of the resistance of the basic characteristics of a culture of unicellular algae (Chlorella) under autonomous cultivation conditions, and within the closed man-algae gas exchange system, showed the presence of spontaneous, periodic oscillations in culture productivity (15 to 20 percent of the mean), of changes in the chemical composition of the biomass (10 percent of the mean), and in the acclimation coefficient (7 percent of the mean). The period of these oscillations was about 20 days. The probable causes of the oscillations are periodic changes in the age composition of the algae population.

Change in illumination of the population by steps resulted in more asynchronous and spontaneous oscillations, and those of productivity, in particular, smoothed out.

The stability of the asynchronous culture influenced by experimental factors was found to be unlike that of life support for cells of different physiological age and was significantly higher than that of the synchronous culture. This fact is of practical importance because in the case of reversible emergency situations, the culture can regenerate because of the cells of the ontogenetically stable stage that were preserved. This property of self-regeneration obviously is one of the most important internal mechanisms for preservation of the stability of the population of the organs in the biological /82 system.

One of the directions taken in the development of biological systems was that of investigating the mineralization of certain of the human metabolism products and parts of the inedible biomass of plants. Confirmed experimentally was the desirability, in many cases, of mineralization of organic waste by the "wet" combustion method in order to recover the mineral elements in the nutrient medium of plants.

3. Exobiology. Research on various problems of exobiology continued in 1970.

Research on the effect of extremely high vacuum, and of superlow temperatures on microorganisms, and their enzymes, underwent further development. Reports made in previous years pointed out that microorganisms of different systematic groups have unlike resistances to the effects of extremely high vacuum. Successfully established recently was the fact that the resistance of many organisms to the effect of this factor can be explained by the presence of a mobile fraction of water on the molecular level which remains stable even when the change in external moisture values covers a wide range. The stability of the fraction of mobile water in dormant forms of life (dry seeds of wheat, beans, yeats) during drying evidently is associated with the compaction of the proteins as water is lost, and of their impenetrability to the residual water. This protects a definite part of the cells against the direct effect of vacuum.

The influence of this unfavorable factor on the activity of certain enzyme systems (adenosine triphosphoric acid, and ferroporphyrins) was studied in order to explain the mechanisms of resistance to vacuum on the part of certain representatives of microorganisms. A comparative study of the homogenate of cells of forms of microorganisms resistant and nonresistant to the effect of vacuum showed the absence of activity on the part of extracellular ferroporphyrin enzymes. Investigations of entire cells of these forms of microorganisms developed two interesting factors: the activity of the ferroporphyrin enzymes increased in both groups; and the enzymes of organisms resistant to vacuum were highly active. Consequently, the cell membrane protects the enzymes under extremely high vacuum conditions in different ways. So far as the adenosine triphosphoric acid is concerned, there was no success in arriving at any principal difference in the activity of this enzyme within the cells, or in the homogenate of the cells.

A comparative study of the effect of the temperature of liquid nitrogen ($-196^{\circ}C$) on some microorganisms revealed that the sensitivity of the various groups of microorganisms to extreme cooling is not the same. Saccharomyces vini and Serratia marcescens were tested. Polarographic and manometer methods /83 were used to determine the oxidation functions.

Serratia marcescens cells exhibited practically the same activity in oxidizing the substrate in the control and in the experiment, whereas the oxidizing capability of the Saccharomyces vini cells decreased sharply after a temperature of -196° had been created. Evidently this difference is connected with differences in the spatial organization of the respiratory chain, as well as with the fact that the formation of intracellular ice crystals does much more damage to large yeast cells than to small bacterial cells.

Further research was engaged in in order to study the evolutionary paths or organic compounds under "primitive" earth conditions when acted on by different types of energy. Interesting data were obtained on the radiation-chemical synthesis of deoxynucleosides from deoxyribose and adenine, guanine, and thymine. Synthesis was brought about by irradiation with cobalt rays (doses of from 5.0 to $100.0 \cdot 10^6$ rad) of dry preparations of carbohydrates and a base in argon. The presence of minerals had a definite effect on the yield of reaction product. CuO and Fe_2O_3 definitely reduced the yield of

deoxynucleosides. Results thus point to the possibility of an abiogenic radiation-chemical synthesis under "primitive" earth conditions.

The work on the abiogenic synthesis of amino acids, of nitrogenous bases, and of carbohydrates under the effects of temperature (temperatures of regions with active volcanic activity) are of interest in this same plan. It was shown that the stability of the amino acids at a temperature of the order of 170°C depends on the length of the carbohydrate chain (the shorter the hydrocarbon chain, the more stable the amino acid). The compositions of the inorganic rocks, on the surfaces of which the synthesis occurs, have a significant effect on the resistance of the amino acids to heating. The effect of the oxides on the decomposition of the amino acids (in the presence of O_2) is to yield the series $ZnO > V_2O_5 \geq SiO_2$, Al_2O_3, $Fe_2O_3 > TiO_2 >$ amino acid > feldspar. The resistance of amino acids to heat depends too on the nature of the atmosphere in which the synthesis occurs. Available data lead to the assumption that amino acids most resistant to heat participated in the long chemical evolution that took place under the effect of heat energy.

As before, the primary problem remains that of detecting life on other planets. Research therefore is continuing to develop methods of detecting extra-terrestrial life.

The existence of optical activity (along with other methods) can be an adequate condition for the establishment of the presence of life on a particular planet as searches are made for possible forms of life on the planets. Chemists /84 however, do not exclude the possibility of abiogenic synthesis of optically active substances under the conditions existing in space. Consequently, the detection of optically active matter in an extract of planet soil cannot, in and of itself, serve as proof of the existence of life. More reliable is the appearance of variations in optical activity, something that would indicate development of microorganisms in the nutrient, or of a requirement for one of the isomers of racemate, as well as one of two optical isomers contained in the medium. Connected with this has been the investigations of the rotation of optically active compounds when acted on by soil microflora. Preliminary data indicate that the change in optical activity when acted on by soil microflora is more rapid the richer the soil is in microorganisms.

The method based on the adenosine triphosphoric acid determination can be used for direct soil analysis only if the soil contains a significant number of microbic cells, and these should be destroyed in advance. A comparative analysis was made of the various methods for destroying cells, and equipment was built capable of detecting 10^{-13} g/ml of adenosine triphosphoric acid.

The best developed of the methods for detecting signs of life is that of the determination of the radioactive carbon contained in the carbon dioxide given off by a mixed culture of microorganisms which decompose the radioactive organic matter in the nutrient. The introduction of radioactive compounds directly into Martian soil, and the subsequent determination of the carbon dioxide given off, is recommended for use in searching for life only when the bacteria content is relatively high, and when the soil is quite damp, something that is necessary for the rapid decomposition of the organic matter by the microorganisms. A new method for detecting life on a foreign planet, based on a study of certain aspects of the gas exchange in the soil-atmosphere system, is under development.

4. Medical and biological investigations of lunar soil. Heat and chemicals were used in accordance with the program for microbiologic investigation of the soil to sterilize Luna 16's boring mechanism rod prior to flight. The vacuum receiving chamber on the ground too was sterilized in order to destroy its "earth" microflora.

There was every reason to expect the existence of anaerobic bacteria resistant to change in temperature, dessication, to vacuum conditions, and the like, in the lunar soil. This is why the corresponding procedures were used under laboratory conditions.

However, these procedures (conventionally used to show up "earth" microflora) failed to detect any forms of microorganisms. This not only points to the absence of microbes, fungi, and viruses in the soil sample investigated, but also to the fact that the device carried by Luna-16 was free of "earth" microflora. /85

It was shown experimentally that neither the soil particulates, nor an aqueous extract of them, had a stimulating or inhibiting effect on the growth of bacteria.

The next stage involved study of the interrelationship between soil particulates and living cells of an organism, and, in particular, the interrelationship with phagocytes. It is known that phagocytes are those cells belonging to the organs of immunity, so are responsible for the protective reactions of the organism. Results have shown that soil particulates were absorbed by animal cells (those of mice, guinea pigs) when the animals were injected subcutaneously, or intravenously, as well as by cells cultured outside the organism. Particulates caused no inflammatory reactions, and, since they were inside the cells, had no toxic effect on them.

The possible toxic effect of the soil on earth organisms was investigated in more detail, using animals in three series of experiments.

The result was to establish that the intraperitoneal injection of aqueous infusions of substance had no significant effect on animal organisms. An intraventricular injection of a suspension, and inhalation with air passed through a layer of the soil, resulted in a moderate number of leukocytes in the blood. Some reduction in the activeness of the cholinesterase of the blood also was noted in the case of the intraventricular injection.

Pathomorphologic and histochemical investigation failed to show any significant changes in the internal organs and tissues of the test animals used in all three series of experiments.

The radiobiological experiments studied the effect of preliminarily injected soil on the radioresistivity of mice. Processing of the data obtained over a two-month period of observations has now been completed, and analysis has failed to reveal any marked effect of the lunar material on the radioresistivity of animals.

The data from all the medical and biological investigations lead to the conclusion that lunar soil has little biologically oriented activity. Future research anticipates observations of the remote consequences of long-term interactions between lunar soil and earth organisms.

VI. Other Investigations /86

1. The Soviet space research program is defined in terms of finding complex, systematic solutions for principal scientific and technical problems. One of its directions is that of building permanent orbital stations to serve science and the national economy. Stations such as these will make it possible to expand considerably the scope of the problems investigated, and to do new scientific and technical experiments.

The most important stage of this journey is the flights of the Soyuz spacecraft, during which principles concerned with control, maneuvering, docking, and the functioning of the various on-board systems are developed and, simultaneously, complex problems that are concerned with the study of our planet from space are solved.

The principal purpose of the flight of Soyuz-9, manned by pilot-cosmonauts A. G. Nikolayev and V. I. Sevast'yanov (orbited on June 1, 1970), was the study of the long-term effect of spaceflight factors on the human body, and to verify the fact that man can work actively under long-term weightlessness conditions. Equally important was the task of studying the process involved in man making the transition to the conditions of the earth's gravity after a long period of weightlessness.

These tasks were carried out along with those of a comprehensive program of scientific, technical, and medical-biological investigations and experiments. The program envisaged the following as part of future improvements in the spacecraft, and its systems;

development of manual control and orientation systems, as well as methods for using autonomous navigation equipment;

check of the orbital correction system and of the descent control system under various conditions;

a series of experiments to investigate the structural members of the spacecraft.

The cosmonauts, during the flight, observed the earth from deep space with optical instruments, photographed geological and geographic objects for /87 purposes of geological cartography, and to establish probable regions of

mineral deposits, and observed and photographed atmospheric formations and snow cover boundaries.

A large part of the program was devoted to special medical and biological research and experimentation for purposes of studying all aspects of the effect the factors involved in long space flight have on the human body.

The process of carrying out the program for the particular flight can be characterized as one with a great many dynamic operations associated with spacecraft orientation, and which were completed in sum several score times. Many of the experiments and observations required that the spacecraft be oriented in advance and then stabilized in that position by gyroscopes. This was a manual procedure, usually, but shifting to automatic was done occasionally. So-called twisting of the spacecraft in order to orient the panels of the solar batteries with respect to the sun was done manually almost every day.

The spacecraft was oriented with respect to the earth several times during the flight, when it was over the earth's shadow side. Automatic, semiautomatic, and manual control modes were used.

The purpose of the technical experiments was to test Soyuz 9 systems on a long flight, to put the finishing touches on the new instruments in the navigation and movement control systems, to determine the structural and dynamic characteristics of the spacecraft, and the external disturbing factors.

A new automatic star orientation sensor providing dependable and accurate orientation of the spacecraft against a background of strong light interferences was flight tested. The tests made it possible to put the finishing touches on the instrument and to select its characteristics in the best manner possible. The visual optical-electronic instrument for manual orientation of the spacecraft on the earth when flying over the shadow side was successfully tested.

The experiments designed to perfect methods and equipment for autonomous orbital navigation continued.

A procedure for finding an operational solution to navigation problems by using the on-board computers was perfected in flight. It also can be used for purposes of redundancy, and to increase the dependability of flight control.

There was a whole series of experiments associated with study of the

structural characteristics of the spacecraft. Measurements of deformations in the spacecraft caused by vacuum conditions and one-sided heating by the sun /88 were made. The spacecraft's inertia characteristics were defined more accurately, and moments of inertia and the alignment of the main axes of inertia were determined. The operation of the precision mechanisms and of the optical units in space was studied. The cosmonauts used optical equipment to determine the accuracy characteristics of the gyroscopic instruments in the orientation and stabilization systems. Investigation of the nature, dynamics, and brightness characteristics of luminous particles, and tests of new, highly accurate illuminators providing for dependable operation of sensitive optical components, continued throughout the flight.

The influence of the aerodynamically and gravitationally disturbed moments on the dynamic characteristics and controllability of the spacecraft were evaluated during the flight.

The crew, in the course of its medical and biological investigations, carried out experiments designed to investigate the functions of the vestibular apparatus, the function of external respiration, the dynamics of arterial pressure, the nature of the sensitivity of the skin to pain, the contrast sensitivity of the eyes, and the conservation of its characteristics by the visual apparatus,the muscular strength of the hands,and muscle-joint sensitivity.

All of these experiments were assigned in order to monitor the condition of the cosmonauts, but were designed primarily for deeper study of man's capabilities, of all of his organs to function normally under the conditions prevailing on a long space flight.

The energy expended by the cosmonauts under flight conditions was calculated in order to obtain data for use in building optimal life support systems, as well as for use in developing scientifically based food rations and water requirements.

The cosmonauts conducted experiments at different stages of the flight to investigate the transient processes involved in the manual control of spacecraft. These experiments were conducted with a special on-board analog computer used to model various dynamic control modes. These experiments made it

possible to determine man's "transfer function" as a basic link in the control system.

The flight also included biologic experiments that provided interesting material on certain questions of genetics and cytology.

Experiments of importance to the national economy took up a good part of the program. During the flight the cosmonauts repeatedly observed and photographed for study the spatial structure of clouds, determined the limits of /89 the snow cover, and located gales, storms, and tropical cyclones.

The ground asked the crew for weather reports on various regions of the globe, and the crew made the observations and reported their results back to the ground. The reports from the spacecraft on weather phenomena were used by the Weather Service in its operational work.

The principal purposes of the experiment involving the photographing of geographic and geologic objects on the earth's surface were to refine existing, and compile new geologic maps for mineral prospecting.

During a combined experiment in the regions of the Northern Caucasus, Caspian and Aral seas, Kazakhstan, and Western Siberia, the spacecraft took photography at the same time that aircraft assigned to geologic reconnaissance made photographic surveys of these same objects.

Measurements of the spectral brilliance of the sun, and of the earth's day and night horizons, were particular aspects of the scientific experiments. The luminous particles outside the spacecraft's ports were observed during the flight, and their size, brightness, distance, and rate of movement, were determined.

The procedures that were to have been used for certain of the experiments were changed in flight. The cosmonauts made the corrections upon recommendations from the Control Center. This resulted in better quality experiments because changed conditions were taken into consideration.

2. The extragalactic source of radio radiation 3C 120 was investigated. From a comparison of the readings obtained by the gamma-telescope carried by Kosmos-251 and Kosmos-264, it is concluded that there is a discrete source of γ-quanta with energy $E_\gamma \geq 100$ Mev. The region of the possible location of the

source is bounded by the coordinates $\alpha = 3.6^h$ to 5.0^h, $\delta = 4^o$ to 9^o. The extragalactic source of radio radiation 3C 120 falls within this region. It emits variable, irregular radiation at 2 to 6 cm wavelengths, and the maximum coincides with the time of observation of the γ-quanta flux. The recorded γ-quanta flux has a magnitude of $(6.0 \pm 2.3) \cdot 10^{-4} (cm^2\text{-}sec)^{-1}$ and a duration of at least $5 \cdot 10^5$ seconds. If the flux is from 3C 120, the power of the flare in γ-rays is $\sim 2 \cdot 10^{47}$ erg/sec. Figure 29 shows the magnitude of the excess reading by the instrument in terms of the angle at which the gamma-telescope "saw" 3C 120. The solid line is for the instrument function of the telescope, obtained during calibration.

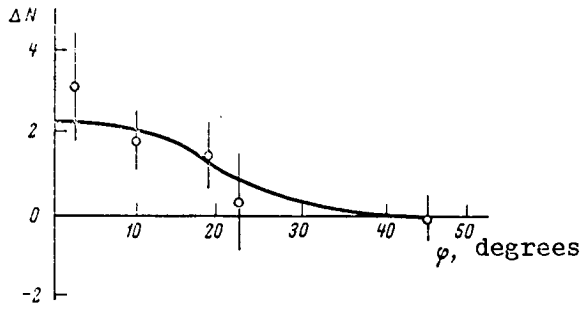

Figure 29. Magnitude of the excess reading of γ-quanta flux from the 3C 120 source, as recorded by the gamma-telescope.

3. Study of X-ray flares on the sun by the equipment carried by Interkosmos-4 (launched October 14, 1970) continued. Polarization of the X-ray radiation from the flares in the ~ 1 Å band was investigated. Preliminary analysis of data on two powerful flares (optical flares classes 2 and 3) confirmed the results obtained by Interkosmos-1 in 1969; there was considerable polarization for a few minutes, until the main maximum of the X-ray flare was reached. /90

The equipment also included a X-ray spectroheliograph. Spectra of the hottest regions of the flares were obtained in the 1.7 to 2 Å band, with resolution 0.001 Å. Observed in the case of both of the above-mentioned flares was a considerable intensity of the Fe XXV ion lines and of the characteristic X-ray lines K_α. Figure 30 is an example of the spectrum. Moreover, the heliograph made bow scans of the sun with 20" resolution simultaneously in two mutually perpendicular directions, recording radiation between 8 and 12 Å, and providing the structure of the active regions.

The rocket Vertikal'-1, launched on November 28, 1970, as part of the Interkosmos program, carried X-ray spectrometers, and at a height of some 500 km obtained the spectra of the active regions of the sun in the $\lambda = 5$ to 19.5 A band.

The instruments were mounted on two tracking systems together with the instruments from Wroclaw University photographing the sun in the X-rays. Four recordings of the spectrum in the 7.5 to 19.5 Å region, and one in the 5 to 8 Å region, were obtained while the instrumentation was operating above 100 km (10 minutes). Reliably recorded in the spectra were the lines for the hydrogen- and helium-like ions of Si, Mo, and Ne, as well as the lines for the ions of Fe XVII, Fe XVIII, and O VIII. The filters provided very high quality spectra, free of scattered light.

The recording X-ray telescope carried by Lun khod 1 investigated the X-ray background in space, as well as discrete X-ray sources. The band was between 2 and 10 Å, the collimator field was circular, with a 3° diameter, and time of /91 one exposure was 6 hours. The belt of the celestial sphere intersecting the plane of the galactic in the region of the constellation Cygnus was scanned. The results are being analyzed.

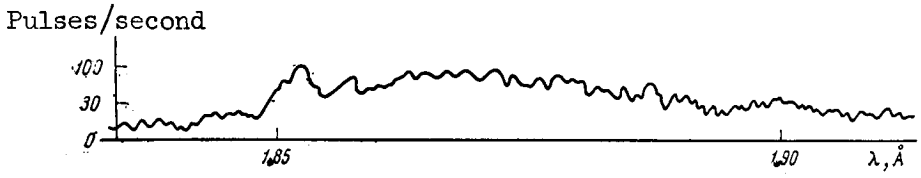

Figure 30. X-ray spectrum obtained by Interkosmos-4 at $08^{h}42^{m}$ UT on October 24, 1970, during a 3B optical flare.

4. A rocket-type astrophysical observatory was launched on October 3, 1970, to make a complex study of the sun and its individual regions. The flight was over a vertical trajectory to a height of about 500 km.

This observatory comprised a set of scientific instruments mounted on a special, oriented and stabilized, platform. Included were several X-ray cameras built to receive radiation on different wavelengths, a unique camera, an extraeclipsing (Lyot) coronograph, designed for taking global photography of the corona at great distances from the edge of the sun's disk, a shortwave spectrograph, a camera for photographing the chromosphere, and others.

Once the planned height was reached, the cover on the container opened automatically, and the observatory became operational. When the program was concluded the cover was closed, the container separated from the rocket, and parachuted back to earth.

Analysis of the photographs showed a small, but extremely powerful source of X-ray radiation at the edge of the sun's disk. Preliminary estimates are that the energy radiated from this source exceeds the total X-ray radiation of the entire "quiet" solar corona. A comparison of the size of this source with the size of the sun leads to the conclusion that its intensity is at least tens of thousands of times greater than the intensity of the radiation from the corona itself. The liberation of a tremendous amount of energy in the form of X-ray flares, or of a strong local source is most possible during thermonuclear processes. These processes usually take place in the stellar and solar interiors. Data from this experiment reveal that these processes can /92 take place in the sun's surface layers, and even in its atmosphere, from time to time.

5. The year 1970, can be characterized as one in which stations were re-outfitted, research was conducted using the meteor method, more modern research procedures were developed, and a global network of radiometric wind stations for researching the planetary circulation of the upper atmosphere was established. A complex of super-powerful radars was placed in service to record meteors with stellar magnitudes of +12 to +14. These sets incorporated accurate altimeters so data on the behavior of the coefficient of ambipolar diffusion with height could be obtained, and the density and temperature of the upper atmosphere studied.

The first equatorial meteor expedition sent out by the Academy of Sciences of the USSR to the Republic of Somali completed its work in 1970. A two-year cycle of complex radar and optical measurements of meteors was made. Over 300,000 measurements of meteor track drifts were obtained. The materials are being processed now. New data on the vertical wind component in the equatorial latitudes at heights of between 70 and 110 km have been obtained.

Measurements of meteor track drifts at another eight points, including those in the Arctic and Antarctic, continued.

Various observatories in the country continued to investigate the rate of meteor track drift under the influence of the earth's magnetic field, velocity of small-scale turbulence in terms of height, seasonal variations in atmospheric density, and other factors.

Statistical azimuthal radar observations of meteors were processed, beginning with 1964. Averaged distributions of the visual density of the radiants from sporadic meteors were obtained. A special feature of the distribution is three maxima: apex, solar, and antisolar. Results concerning the fluctuations that occur in the space density of meteors during the year also were obtained.

6. The radiant heat exchange with the nose of a blunt body as it moves in air in the range v_∞ = 10 to 16 km/sec was investigated. Line radiation from atoms and ions makes a significant contribution to total radiant heating. Systematic research on the aerodynamics of heat exchange of segmental bodies also was conducted. The possibility of the formation of a pendulous shock wave on the lee side as a result of the flow around elongated bodies at angle of attack has been pointed out. Calculations of the nonequilibrium flow around the frontal section of a segmental body at angle of attack, and calculations of front and side surface boundary layers in the case of a three-dimensional flow around the body, were made.

The influence of molecular transfer processes as bodies move in the upper /93
layers of the atmosphere is substantial. A continuous zone of viscid flow forms ahead of the body, rather than a shock wave and a boundary layer. A method for arriving at a numerical solution to the Navier-Stokes equation for arbitrary Reynolds numbers was developed, and numerical methods were used to show that with increase in Re comes the formation in front of the body of a narrow zone of sharp change in parameters which becomes a shock wave when $Re \to \infty$.

The year 1970 saw the completion of the research on the kinetics of the excitation and dissociation of molecules of oxygen and nitrogen at the high temperatures occurring in front of the nose cones of vehicles entering the earth's atmosphere at hypersonic speeds. The values of the dissociation reaction rates, and the times of vibrational relaxation, were measured for temperatures up to 15 to 20 thousand degrees. The phenomenon of reduction in the time of vibrational relaxation with the development of the excitation process, associated with the anharmonicity of molecule vibrations, was studied. A considerable increase in the dissociation reaction rates in the near-equilibrium region of the flow because of the influence of the beginning of recombination

was found. Systematic research on the structure of the strong shock wave propagating in the earth's atmosphere at up to 10 km/sec, and which took into consideration the kinetics of excitation, dissociation, and ionization of molecules, was completed. The elastic interaction of molecules and atoms in a heated gas was investigated, and the kinetic coefficients (of viscosity, thermal conductivity, diffusion) needed for use in making calculations of the flow around bodies moving in the atmosphere of the air, and of other planets, was investigated.

Results of experiments in the field of high-speed impact were processed and systematized in 1970.

Established was the fact that when collison speed is high enough, the interaction of a flying body with a semi-infinite barrier becomes explosive in nature. The depth of the cavern (crater) that forms under this impact decreases, but its diameter increases sharply. It was found that the penetrative capability of particles impacting the barrier at velocities in excess of 18 to 20 km/sec was less than that of particles doing so at 11 to 13 km/sec. The relationships obtained made possible a new interpretation of the results of experiments concerned with the penetration of panels made of different materials in space and to merge these results with the results of measurements made of the number of sporadic micrometeors obtained by using microphone pickups.

7. The development of a high-speed procedure for determining the orientation of an artificial earth satellite by using measurements of the earth's magnetic field intensity vector, supplied by the satellite, was completed in 1970. This procedure is accurate enough to interpret the readings from the /94
scientific equipment and to do the operational processing of the great volumes of measurement information obtained. This procedure was used to process the magnetometric information received from Proton-2, Proton-4, and Kosmos-196. The result of the use of this procedure, together with the data on the orientation of the scientific equipment in space, is a picture of the changes in the parameters characterizing the rotation of the artificial earth satellite around the center of mass in terms of time, something that is distinctively different about the Proton satellites. Figure 31 shows the trace of the vector of the kinetic moment of Proton-4 in absolute space. Figures are for the revolutions. It was found that there are long-period (25 to 30 revolutions)

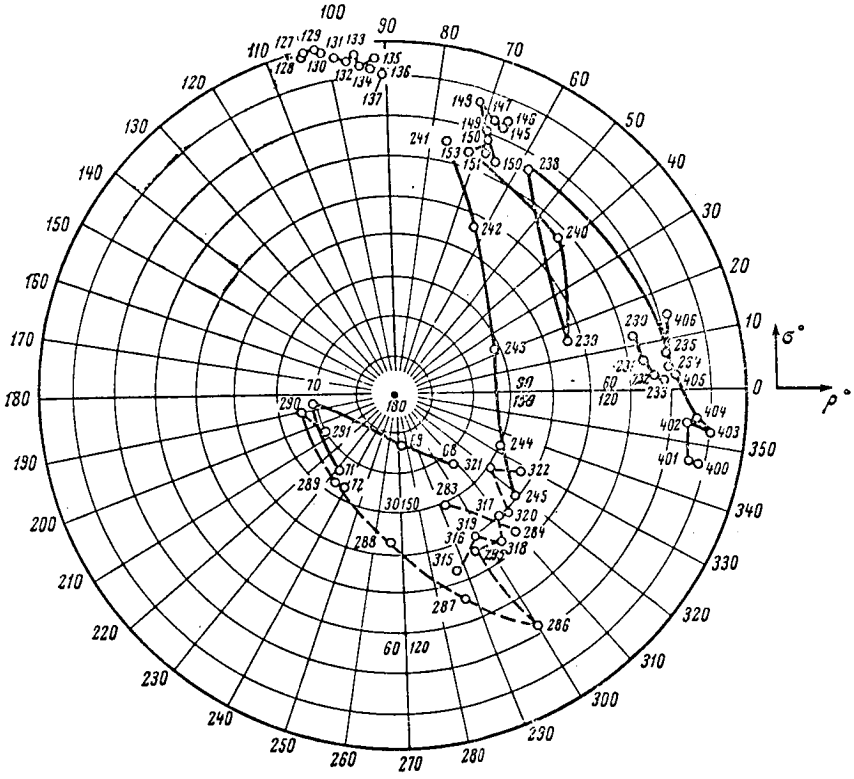

Figure 31. Trace of the kinetic moment vector for Proton-4 in absolute space.

variations in velocity and mode of rotation about the center of mass in the case of the Proton type satellites, with the velocity change from 0.5 to 3 degrees per second. This rotation is connected with the effect of the aerodynamic moment, the great magnitude of which can be explained by the sizes of the solar cell banks and the height of the perigee of the orbit. /95

8. Molniya-1 communication satellites were launched on February 19, June 26, September 29, November 27, and December 25, 1970, to support the operation of the long distance telephone and telegraph radio communication system, as well as to transmit programs broadcast by Central Television in the USSR over the "Orbita" network of stations located in individual regions of the country, access to which is difficult. The expansion of this network continued. The construction of ground stations in the cites of Okha, Zeya, Uray, Sovetskaya Gavan', and Bilibino was completed. Programs broadcast by Central

Television via Molniya-1 communication satellites will be received by 35 stations by the beginning of 1971. The construction and planning of a number of new stations continues.

Steps taken to further improve the technical capabilities of ground stations, as well as of the entire space communication system, and to more fully utilize those capabilities, have been successful.

The number of cities with telephone communication with Moscow over the satellite communication lines has increased.

VII. International Collaboration

/96

Research on deep space by the Soviet Union in collaboration with the socialist countries, France, and other states, continued in 1970.

Work under joint programs was carried out in the field of space physics, meteorology, communication, space biology, and medicine.

Collaboration with the socialist countries in investigating the physical properties of deep space included joint efforts in studying the upper atmosphere, the magnetosphere, sun and solar-earth communications, cosmic rays, the solid component of interplanetary matter, and geophysical and geodesic research using observations made from artificial earth satellites.

Kosmos-321, carrying the Soviet-built coherent radio transmitter "Mayak," was launched on January 20, 1970, in order to solve problems of upper atmosphere research. The transmitter's signals were received by ground receivers in Bulgaria, the German Democratic Republic, Cuba, Poland, Rumania, the Soviet Union, and Czechoslovakia. The data obtained were used to calculate the total content of electrons, the scale of the inhomogeneity in the concentration of particles and other of the characteristics of the ionosphere. This research is a continuation of the work that was begun by Interkosmos-2 (launched on December 25, 1969), which carried a coherent radio transmitter manufactured by experts in the German Democratic Republic. The results of the two experiments were discussed at a joint seminar of experts from the participating countries in November 1970.

Kosmos-348 was launched on June 13, 1970, to continue the work begun by Kosmos-261, which had been launched in January 1968, in measuring variations in upper atmosphere parameters associated with aperiodic disturbances in solar activity. It has been tradition for many of the socialist countries to participate in work along this line, with their efforts devoted to carrying out a broad and varied program of joint ground measurements while the satellite is functioning.

Upper atmosphere research also was carried out by the rocket Vertikal'-1, /97 the first geophysical rocket, which was launched on November 28, 1970, in accordance with the program for collaboration with the socialist countries in deep space research. Concentrations of electrons and positive ions, and

electron temperature, were measured and the distribution of these parameters in terms of height was determined. Equipment was manufactured in the German Democratic Republic and in the USSR. Bulgarian and Czech experts participated in equipment design. A significant contribution to the investigation of short-wave radiation from the sun was made by the scientific equipment developed by experts in Poland, the Soviet Union, and Czechoslovakia and installed in a special, recoverable container in the rocket. The recovery of the equipment, envisaged in this experiment, resulted in photography of solar phenomena at various wavelengths being obtained on the ground for future laboratory analysis. Hungarian, Czech, and Soviet experts also used this rocket to investigate meteor particles.

Interkosmos-3 (launched on August 7, 1970) carried Czech and Soviet equipment to investigate the magnetosphere and cosmic rays. The four months of active functioning of this satellite resulted in the obtaining of much scientific material which now is being processed and analyzed by those who took part in the work. Observatories in Bulgaria, the German Democratic Republic, Poland, the USSR, and Czechoslovakia participated in the accompanying ground measurements.

Interkosmos-4, launched on October 14, 1970, investigated shortwave radiation from the sun and its influence on the structure of the earth's upper atmosphere. These measurements continued the work begun by Interkosmos-1 (launched on October 14, 1969). The equipment for this purpose was improved by its developers, experts in the German Democratic Republic, the USSR, and Czechoslovakia. Observatories in Bulgaria, Hungary, the German Democratic Republic, Poland, Rumania, the USSR, and Czechoslovakia, carried out programed radioastronomical, ionospheric, and optical observations simultaneously with those made by the satellite. Chapter II contains a detailed description of these efforts.

Among the other joint efforts, those by the ground observatories in the collaborating countries made a significant contribution during this past year. These investigations were made simultaneously with satellite observations, as well as within the framework of independent joint programs. To be noted in particular among these latter is the joint effort to observe artificial earth

satellite movement, an effort that has yielded a wealth of material for research in the fields of geophysics and geodesy. An important point about these investigations is the decision to develop joint efforts in the field of laser observation stations. Equipment for making similar measurements is being built in a number of the collaborating countries under agreed plans. /98

Joint efforts to investigate the physical properties of deep space were discussed at the 7th Conference of the Franco-Soviet Working Group (Yerevan, November 1970), at which time summaries of joint experiments already in progress were presented.

An important stage of the work in the field of laser location of the moon was completed in 1970. Luna 17 delivered a laser reflector manufactured by French experts to the surface of the earth's natural satellite. Successful observations made in the Soviet Union by the Crimean Astrophysical Observatory of the Academy of Sciences of the USSR, and in France by the Pic du Midi Observatory, provided independent, highly accurate measurements of earth-moon system parameters. In the very first experiments the distance to the laser reflector was measured with an error of ±3 meters.

Important stages of other joint projects also were completed, particularly:

successful observations of movements of artificial earth satellites by the Franco-Soviet station for optical observations on Kerguelan Island (France) equipped with the AFU-75 automatic camera;

the next scheduled stage of the investigation of the magnetosphere by automatic balloons and ground equipment in the magnetically contiguous regions, Arkhangel'skaya Oblast' (USSR) - Kerguelen Island (France);

continuation of observations of galactic sources of radio radiation with Soviet equipment on the French radio telescope in Nancy.

In 1970, preparations were made for other experiments, accomplishment of which is planned for the near future.

The USSR was successful in developing collaboration with other countries in the field of space communications. Particular attention was given to strengthening and expanding this collaboration with the socialist countries.

Work continued on the establishment of an international system and on the organization of space communications, "Intersputnik."

Experts in the USSR and in France have developed ways to further improve the quality of the communication line between Moscow and Paris via the communication satellites Molniya-1. Efforts to automate the monitoring and measuring of quality of television channels via these same satellites were summarized. /99

Experimental transmissions of color television signals by the SEKAM system via the Moscow-Paris space line were sent in February, August, and September 1970.

The joint efforts of Soviet and French specialists in this field resulted in high quality transmissions via the Molniya-1 communication satellite of color television programs, complete with the audio, reporting the arrival in the USSR in October 1970, of President Georges Pompideau of France.

The planning of joint scientific research by the socialist countries in the field of space meteorology continued, and measuring equipment for rocket experiments was developed.

Scientific summaries of joint efforts in 1968 and 1969, were presented to the spring 1970 symposium on satellite meteorology at the Hydrometeorological Center in the USSR.

The III Conference of the Permanent Working Group on Space Meteorology met in Cracow (Poland) in April 1970. The conference reviewed the results of joint work done, refined working plans and programs for future research, and discussed suggestions for future planning for the 1971-1975 period.

Preliminary work is in progress for joint measurements in the near future of wind and atmospheric density by the falling spheres method. The equipment for these experiments has been manufactured by experts in the German Democratic Republic.

A series of experimental comparative measurements of drifts of meteor tracks were made in September 1970, using Soviet radio equipment installed in the German Democratic Republic, during which valuable data were obtained.

Joint efforts on the part of the USSR and the German Democratic Republic have begun on the building of spectral equipment with high resolution for vertical probing of the atmosphere in the infrared region with meteorological satellites.

Experts from the USSR, the German Democratic Republic, and Czechoslovakia have been testing ground equipment for receiving images of cloud cover transmitted by weather satellites using direct transmissions.

In September 1970, Soviet and French scientists conducted the third joint experiment on the simultaneous photographing of cloud cover over France by /100
the Soviet weather satellites Meteor-4 and Meteor-5 and the French spherical probes Coulomb.

Nine Soviet MR-12 rockets carrying French and Soviet equipment for studying the temperature of the high layers of the atmosphere using artificially illuminating clouds were launched from Hayes Island (Franz Josef Land) in the spring of 1970.

Simultaneously cycles of measurements of wind at heights of from 80 to 100 km, using radar to follow meteor tracks, are in progress in accordance with an agreed program in Garche (France) and Obninsk (USSR).

Materials from the experiments conducted in 1969, with the Dragon-PB rockets have been processed.

In the field of space biology and medicine, work continued by experts from the socialist countries on space physiology, radiation safety on space flights, and in seeking means of providing pharmacological-chemical protection against ionizing radiation from deep space.

Discussed at the Scientific Symposium on Problems of Space Biology and Medicine (Budapest, September 1970) were some of the summaries of joint research, plans were agreed upon, and programs for the 1971-1975 period were developed.

Active work was done in 1970 on the writing of the joint Soviet-American Foundations of Space Biology and Medicine. Two meetings of the joint editorial board were held and it was stated that the writing of the first stage of the work is moving along quite successfully. The exchange of preliminary materials by chapters is in excess of 50 percent, and there is every reason to believe

that the first stage will be completed by July 1971. The authors of ten chapters have been named. It is the responsibility of the authors to combine Soviet-American data and to write the final version of the chapters indicated.

Two of them should be delivered to the editorial board by July 31, 1971, so they can be reviewed at the next joint meeting in September in Moscow.

It can be assumed that the editorial board will name the authors for the chapters in all three volumes of the work at the next meeting.

VIII. Launches of Space Vehicles in the USSR in 1970

/101

No.	Date of launch	Name of vehicle	Apogee, km	Perigee, km	Inclination of orbit to plane of equator, degrees	Period of revolution, min.	Notes
	January						
1	9	Kosmos-318	295	204	65	89.3	
2	15	Kosmos-319	1537	209	82	102	
3	16	Kosmos-320	342	240	48.5	90	
4	20	Kosmos-321	507	280	71	92	
5	21	Kosmos-322	337	200	65.4	89.7	
	February						
6	10	Kosmos-323	333	206	65.4	89.7	
7	19	Molniya-1	39,175	487	65.3	11 hours 43 min	
8	27	Kosmos-324	492	283	71	92	
	March						
9	4	Kosmos-325	348	207	65.4	89.8	
10	13	Kosmos-326	393	212	81.4	90.2	
11	17	Meteor	643	555	81.2	96.4	
12	18	Kosmos-327	855	279	71	95.6	
13	27	Kosmos-328	340	213	72.9	89.7	
	April						
14	3	Kosmos-329	240	202	81.3	88.8	
15	7	Kosmos-330	548	514	74.1	95.2	
16	8	Kosmos-331	347	213	65	89.9	
17	11	Kosmos-332	786	755	74.5	100	
18	15	Kosmos-333	265	217	81.4	89.1	
19	23	Kosmos-334	508	281	71	92.1	
20	24	Kosmos-335	415	254	48.7	91	
21	25	Kosmos-336-Kosmos-343	1500	1400	74	115	Satellites orbited by one carrier rocket /102
22	28	Meteor	736	637	81.2	98.1	
	May						
23	12	Kosmos-344	347	206	72.9	89.8	
23	20	Kosmos-345	276	193	51.8	89.1	
	June						
25	1	Soyuz-9	220	207	51.7	88.59	
26	10	Kosmos-346	289	201	51.8	89.3	
27	12	Kosmos-347	2073	223	48.4	108	
28	13	Kosmos-348	680	212	71	93	
29	17	Kosmos-349	350	203	65.4	89.8	
30	23	Meteor	906	863	81.2	102	
31	26	Kosmos-350	267	204	51.8	89.06	

No.	Date of launch	Name of vehicle	Apogee, km	Perigee, km	Inclination of orbit to plane of equator, degrees	Period of revolution, min.	Notes
32	26	Molniya-1	39,280	470	65	11 hours 45 min.	
33	27	Kosmos-351	494	282	71	92	
	July						
34	7	Kosmos-352	309	205	51.8	89.5	
35	9	Kosmos-353	309	211	65.4	89.4	
36	29	Kosmos-354	208	144	50	-	
	August						
37	7	Interkosmos-3	1320	207	49	99.8	
38	7	Kosmos-355	342	202	65.4	89.7	
39	10	Kosmos-356	600	240	82	92.6	
40	17	Venera-7					Vehicle reached the surface of Venus on 15 December
41	19	Kosmos-357	500	282	71	92	
42	20	Kosmos-358	549	517	74	95.2	
43	22	Kosmos-359	910	210	51.5	95.5	
44	29	Kosmos-360	318	209	65	89.5	
	September						
45	8	Kosmos-361	326	207	72.9	89.6	
46	12	Luna-10					Vehicle made a soft /103 landing on the moon on 20 September. Ascent stage automatically launched from lunar surface on 21 September. Descent vehicle delivered lunar soil sample to earth on 24 September.
47	16	Kosmos-362	854	281	71	95.7	
48	17	Kosmos-363	324	210	65	89.6	
49	22	Kosmos-364	330	211	65.4	89.6	
50	25	Kosmos-365	210	144	49.5	-	
51	29	Molniya-1	39,300	480	65.5	11 hours 46 min.	
	October						
52	1	Kosmos-366	310	206	65	89.5	
53	3	Kosmos-367	1030	932	65.3	104.5	
54	8	Kosmos-368	421	212	65	90.6	
55	8	Kosmos-369	534	278	71	92.3	
56	9	Kosmos-370	307	208	65	89.5	

No.	Date of launch	Name of vehicle	Apogee, km	Perigee, km	Inclination of orbit to plane of equator, degrees	Period of revolution, min.	Notes
57	12	Kosmos-371	780	754	74	99.9	
58	14	Interkosmos-4	668	263	48.5	93.6	
59							
60	15	Meteor	674	633	81.2	97.5	
	16	Kosmos-372	828	786	74	100.8	
61	20	Zond-8					Made earth landing on 27 October
62	20	Kosmos-373	553	490	62.9	94.8	
63	23	Kosmos-374	2153	536	63	112.3	
64	30	Kosmos-375	2164	538	63	112.4	
65	30	Kosmos-376	311	216	65.4	89.5	
	November						
66	10	Luna-17					Made soft landing on the moon on 17 November, delivering Lunokhod-1, the automatic, self-propelled vehicle to the lunar surface
67	11	Kosmos-377	305	208	65	89.4	
68	17	Kosmos-378	1763	241	74	105	
69	24	Kosmos-379	253	198	51.6	88.7	
70	24	Kosmos-380	1548	210	82	102.2	
71	27	Molniya-1	39,430	435	65.3	11 hours 47 min.	
	December						
72	2	Kosmos-381	1023	985	74	105	
73	2	Kosmos-382	5040	320	51.58	2 hours 23 min.	
74	3	Kosmos-383	293	208	65.4	89.3	
75	10	Kosmos-384	314	212	72.9	89.5	
76	12	Kosmos-385	1005	982	74	104.8	
77	15	Kosmos-386	275	207	65	89.2	
78	16	Kosmos-387	560	528	74	95.3	
79	18	Kosmos-388	532	281	71	92.3	
80	18	Kosmos-389	699	655	81	98.1	
81	25	Molniya-1	39,600	480	65	11 hours 52 min.	

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